



Emotional driving in AI-powered Cars; Driver and traffic safety.

Emotion tracking and route prediction, alongside rewarding and education for good driving behaviour.

Master's thesis in Master Interaction Design and Technology

Florian Wachter

MASTER'S THESIS 2019

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CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
Gothenburg, Sweden 2019

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Cover: Knight Rider, an iconic science fiction series of an AI car from the 1980s.[37]

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AI which supports in driver and traffic safety situations
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Abstract

Every year, individuals lose their life in traffic accidents triggered by human errors. The automotive industry intends to create autonomous driving to fix this issue by getting rid of the greatest safety issue, the driver himself. But in this area, the industry faces major problems with law regulations and technological difficulties.

In collaboration with Volvo cars and Volvo's vision, that no one should be killed or seriously injured in a new Volvo by 2020. This dissertation investigates how human errors created by emotional driving or bad driving styles can be minimized with the help of artificial intelligence assistance's instead of using fully autonomous driving vehicles. Along Volvo Car's design strategy including safety, intelligent, modern and warmth, a concept has been created in which cars can detect human emotions.

For this purpose, methodology was conducted in a design thinking structure and various literature sources were reviewed, expert interviews were conducted at Volvo Cars with data analytics specialist and consumer researcher, as well as a psychologist focusing on behavioral therapy. Within the design methodology, such as problem statement and brainstorming, a variety of ideas were created, focusing on angry driving in traffic.

The outcome of the thesis includes an investigation into safety-critical emotions in traffic and a design concept that minimizes critical errors created by angry driving and bad driving style.

The design concept has been tested iteratively with formative usability evaluation and summative usability evaluation in support with lo-fi and hi-fi prototyping on smartphones and tablets. The design concept in its final state, called Volvo Intuit, has three features such as "prevention" that takes care of planning a route to a destination in a trouble-free manner with the support of an AI and an emotional traffic heat map, "education" that includes the approach of educating users in good driving style, and "motivation" that rewards the user for good driving style.

As discovered from research, when negative emotions (such as anger or sadness) occur, they are difficult to eliminate and can result in an emotional increase if handled incorrectly. Consequently, the author recommends that preventive and reactive strategies should be implemented if driving with emotions occurs in traffic to avoid errors and misbehaviour.

Keywords: Traffic Safety, driver Safety, Artificial Intelligence assistance, Florian Wachter, Interaction Design, UX Design, Master Thesis, Anger, Stress, Sadness, Emotional Driving.

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Glossary

Artificial General Intelligence (AGI) Artificial General Intelligence, also called Strong AI, Full AI, is capable to perform any intellectual task as a human. This is still a vision and a common topic in science fiction and future studies. . 13

Artificial Intelligence (AI) "The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages."[80] "The field of AI first flourished in the 1960s as the concept of universal computation, the cultural view of the brain as a computer, and the availability of digital computing machines came together to paint a future where computers were at least as smart as humans."[15] . 1

Artificial narrow intelligent (ANI) An Artificial Narrow Intelligent also called Weak AI, is an Artificial intelligence which is focused only on one task. . 13

Deep-Learning (DL) In the field of computing it means, "a type of artificial intelligence that uses algorithms (sets of mathematical instructions or rules) based on the way the human brain operates"[16] . 13

Humand Machine Interaction (HMI) Human Machine Interactions or HMI is a term that describes an interaction with a device or software that controls a machine. . 3

Machine Learning "The capacity of a computer to learn from experience, i.e. to modify its processing on the basis of newly acquired information."[82] . 13

Neural Network (NN) "A computer system modelled on the human brain and nervous system."[83] . 13

User Experience Design (UX Design) User experience Design or UX Design is about creating products with a high degree of meaningful and relevant experiences to users.[74] . 3

1

Introduction

More than 1.35 million individuals lose their life in traffic accidents worldwide every year. Human errors causes the vast majority of these accidents[46]. One reason for traffic errors can be drivers experiencing negative emotions while driving, which can lead to poor driving behavior, risky maneuvers or, in the worst case scenarios, traffic accidents[52]. Autonomous driving (AD) has been announced as the solution to this problem, but the automotive industry is facing a major change with law regulations and technological difficulties in the area.[61]. This forces the automotive industry to go more on Artificial Intelligence (AI) powered assistance technology's in order to satisfy new customer needs and stay competitive in the automotive industry.

The main advantage of implementing AI is that AI is able to do reasoning which makes it possible to design new systems for driver and traffic safety. For instance, if an AI system tracks a driver, the AI can classify the driver's emotional state and, depending on the current traffic situation, it can reason which risks can occur. This makes it possible to design for preventing negative emotions while driving and also to educate for better driving behavior resulting in more trouble-free driving experience.

In addition, good driving behavior not only has an impact on the driver and other drivers in traffic, it also has a beneficial impact on maintenance costs and environmental such as less CO2 combustion and electric vehicle batteries resting longer.

1.1 Aim

This thesis aims to investigate: firstly, traffic safety critical emotions while driving and, secondly, to develop a design concept which minimizes traffic safety critical errors caused by emotional driving or a bad driving style.

1.2 Research Questions

The following research questions are targeting with this report:

1. Which emotions cause significant harm to the driver and other road users when driving?
2. How to minimizes traffic safety critical errors caused by emotional driving or a bad driving style.

2

Background

This project is a collaboration with Volvo cars and the User Experience Design department, which is focused on User Experience Design (UX Design), User Experience Mechatronics and core Humand Machine Interaction (HMI) Logic. This includes User interface design, Illumination Design, Animation, Concept Design, App Design, and Hi-fi Prototyping in Volvo test cars.

With a strong focus on UX Design, Volvo wants to explore the potential of the AI trend in cars in order to meet new customer needs and stay competitive in the automotive industry.

In combination with the capabilities of AI (3.3 Artificial Intelligence) and the factors of Volvo's design strategy (safety, intelligent, modernity and warmth), the author and Volvo have created a vision in which cars can detect human emotions. The goal is to design a concept to minimize traffic safety errors or traffic misbehavior.

2.1 Purpose

Accidents in traffic are an existing fact and the automotive industry is constantly keeping track of these issue by inventing safer cars. For example, inventions like the "Safety Belt" (The Safety Belt was created by Volvo in 1959[3]) or ADAS (Advanced Driving Assistance System) systems, cover a wide range of safety in cars.

According to the research paper Fang Chen, "How shall we design the future vehicle for Chinese market" there are several underlying problems for driver's misbehavior in traffic situations which result in traffic accidents. For example misbehavior like aggressive driving, bad driving habits, poor understanding of other road users, and poor respect of traffic regulations [13].

Now, with the introduction of AD, the car industry is attempting to go one step further by eliminating the biggest safety issue - the driver himself.

However, autonomous driving is directed by law regulations, social acceptance, and technical challenges which makes it difficult in the near future to produce fully autonomous-driving cars, which are accessible to the public society.[61]

2. Background

In consequence, until the government, society and technology are ready for this step, the car industry must focus on driver support and AI.

AI enables a wide range of new possibilities to interact with a user while driving, for instance, "virtual assistants"[7] can be connected to emotional detection in order to create an intelligent car which acts proactive and adapts to user needs.

3

Theory

The Theory chapter considers theory, examples, technologies, and frameworks in the field of emotions, AI, the automotive industry, and interaction design.

William Gaver argues in its paper "What Should We Expect From Research Through Design?[29]: that X will not always lead to successful designs, "Design often addresses wicked problems which are complex enough that no correct solutions exist a priori and for which formulating the situation is integral to addressing it [29, p.940]". In order for a problem to be best resolved, the author has to examine many different fields, from science to design, to develop a solution that solves the problem as far as possible.

3.1 Emotions

When people think about emotions, they think about feelings at the same time, but emotions and feelings are different things. Feelings are subjective emotional experiences driven by conscious thoughts and reflections. Emotions, on the other hand, describe physiological conditions and are subconsciously generated.

3.1.1 Basic Emotions

Basic emotions are highly discussed and there are different opinions on their definition. The author compared in the following the definition of basic emotions from Paul Eckman, Aristotle's, and Robert Plutchik.

Aristotle's was a Greek philosopher. He argued that basic emotions consisting of 10 Emotions [27] (3.1 Basic Emotions according to Aristotle's).

Paul Eckman a psychologist identified 6 basic emotions, which he expanded later with : pride, shame, embarrassment, and excitement[21] (e.g 3.2 Basic Emotions according to Paul Eckman).

Robert Plutchik a psychologist put emotions together into a wheel (3.1.2 Plutchik's Wheel of Emotions) of emotions (shown in figure:3.1 Plutchik's Wheel of Emotions [25]), which consists out of 8 basic emotions (3.3 Basic Emotions according to Robert Plutchik).

Table 3.1: Basic Emotions according to Aristotle’s

Emotion	Description
Anger	opposite of calmness
calmness	the opposite of anger
Friendship	people have a bond of joy
Fear	opposite courage
Shame	opposite confidence
Kindness	be good to other people
Pity	feeling sorry for others
Indignation	feeling angry because something is not fair
Envy/jealous	pain for having wishes for oneself
Love	a strong emotion of attachment one feels for someone else

Table 3.2: Basic Emotions according to Paul Eckman

Emotion	Description
anger	opposite of calmness
happiness	opposite of sadness
sadness	feeling of loss
disgust	feeling of aversion or disapproval
fear	opposite courage
surprise	feeling when unexpected happens
pride	arrogant assumption of superiority
shame	painful feeling that’s a mix of regret, self-hate, and dishonor
embarrassment	feeling of self-consciousness, awkwardness or shame
excitement	feelings of great enthusiasm and interest

Table 3.3: Basic Emotions according to Robert Plutchik

Emotion	Description
anger	opposite of calmness
Fear	feeling of being afraid, frightened, scared
Sadness	feeling of loss
Joy	feeling happy
Disgust	feeling of aversion or disapproval
Surprise	being unprepared for something
Trust	in which confidence is placed
Anticipation	looking forward positively to something

In a comparison of Aristotle’s, Paul Eckman, and Robert Plutchik they all agree to **anger** and **fear** to be a basic emotion.

3.1.2 Plutchik’s Wheel of Emotions

The Plutchik’s Wheel of Emotions (see fig:3.1) is a tool to simplify a very complex concept of emotional outcomes. Plutchik argues that emotions can be combined

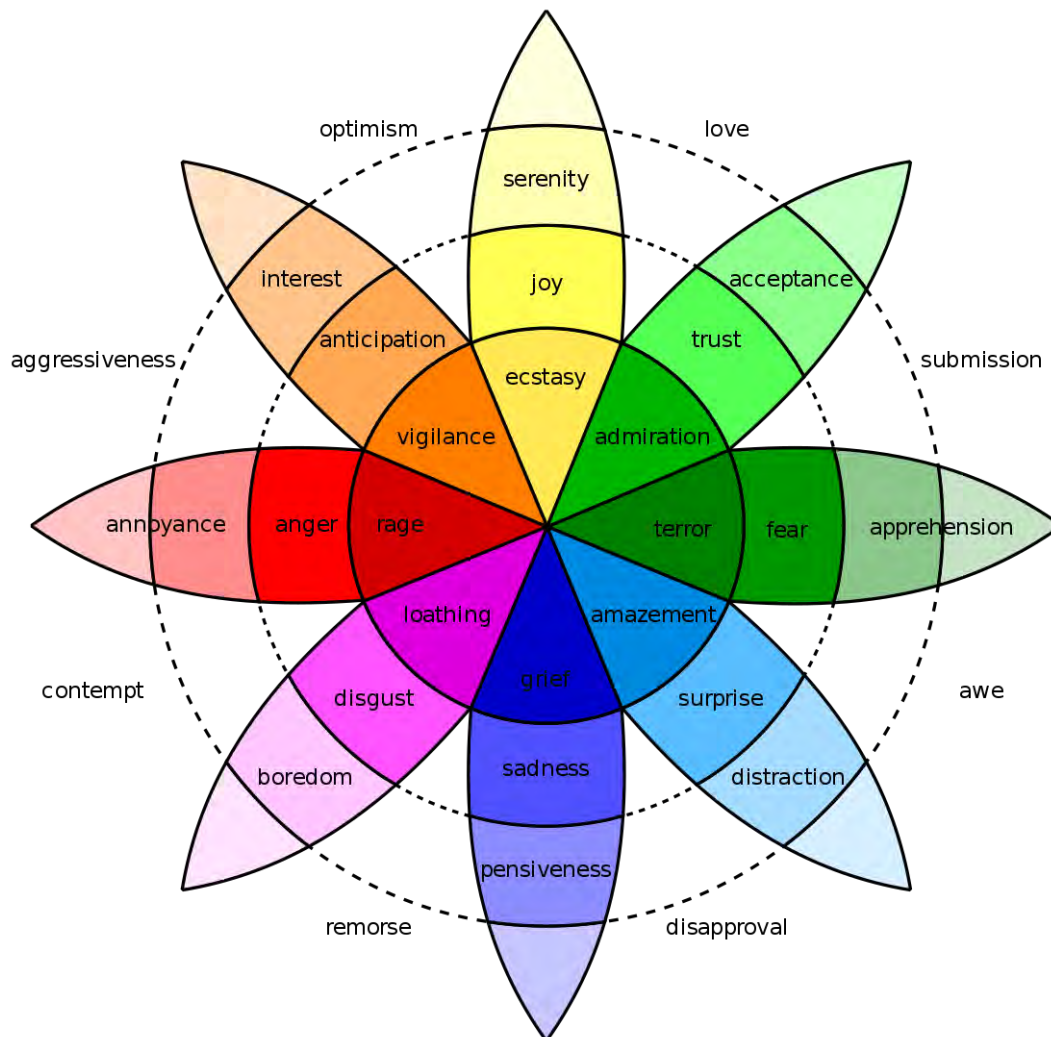


Figure 3.1: Plutchik's Wheel of Emotions [25]

into feelings, such as colors that can be combined to create shades. For example, to create love, joy and trust can be combined (shown in figure: 3.3).[47]

The wheel can be used to discover what are the primary emotions and how to combine them to create secondary emotions.[62] This is important in order to do reasoning on emotions, which can occur in context. For instance, if anger and anticipation come together in traffic situations aggressiveness can be the result.

Plutchik went one step further and created the "Plutchik's Sequential Model" (shown in figure:3.2) that describes the emotional behavioral reaction from stimulus event and function. This model makes it easy to understand the needs of users in an emotional moment. For example, Anger: If a driver wants to arrive quickly and a car in the front is driving slowly, this represents an obstacle for the driver as a stim-

ulus event. Now, the car in the front metamorphoses into a cognitive appraisal of being the enemy and the driver is driving closer to the car in the front as a behavior reaction of attacking with the intention to get rid of the obstacle.

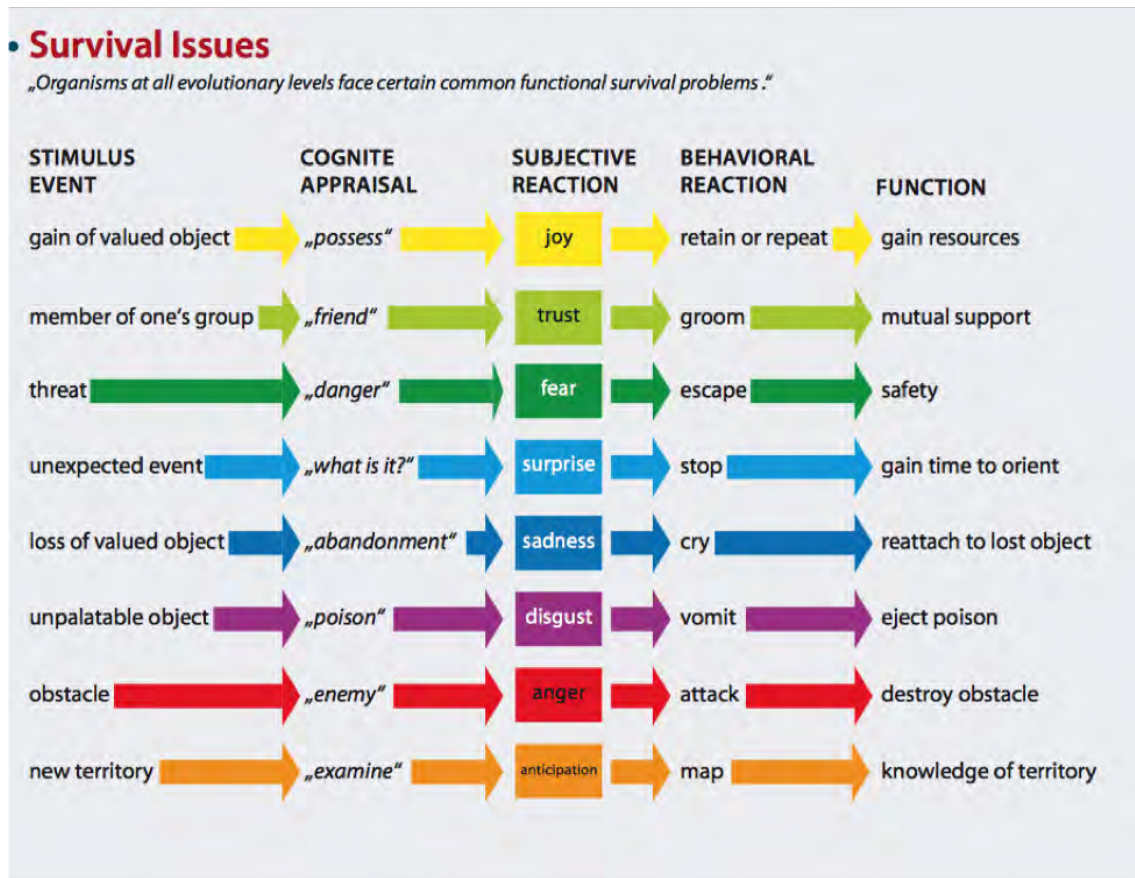


Figure 3.2: Robert Plutchik's Psychoevolutionary Theory of Basic Emotions Poster - Survival Issues[1]

3.1.3 Geneva Emotion Wheel

In comparison to Plutchik emotion wheel (shown in figure:3.1), the Geneva Emotion Wheel (shown in figure:3.4) visualizes 20 emotions (in its second version) and focuses on Valence and situation control. The wheel is divided vertically in Negative and Positive Valence, and vertically in high and low situation control or high-arousal and low-arousal.

3.1.4 Emotional Dimensions

In order to distinguish emotions, emotion can be classified into two dimensions. First, arousal, which is a quantitative dimension. It describes the intensity of the emotion from low to high arousal. For example low arousal occurs while sleeping



Figure 3.3: Robert Plutchik's Combinations and Opposites[1]

and high arousal while have pain or experiencing anger or amusement (3.1.4 Emotional Dimensions). In particular, high arousal is a problem because it decreases the perception of danger and can lead to dangerous circumstances in traffic.

Secondly, valence, which is a hedonistic value that corresponds to the nature of the emotion and defines the emotion into a negative or positive emotion.[49] In the case of valence, negative emotions are not necessarily something negative. They exist to alert people that something needs to be changed and to motivate the change. For example, Anger shows that our well-being has been threatened and something needs to change to return to normal state or fear is an appeal to increase your level of safety (shown in figure:3.2). Negative emotions impacting the body and mind, which is not only uncomfortable, it can also lead to health issues and unappropriated behavior. In case of anger and traffic safety, drivers reacting differently from each other but in general less thought through on their behavior. Emotions not only alert us, but they also help us to make quick decisions which are often risky in case of traffic safety.

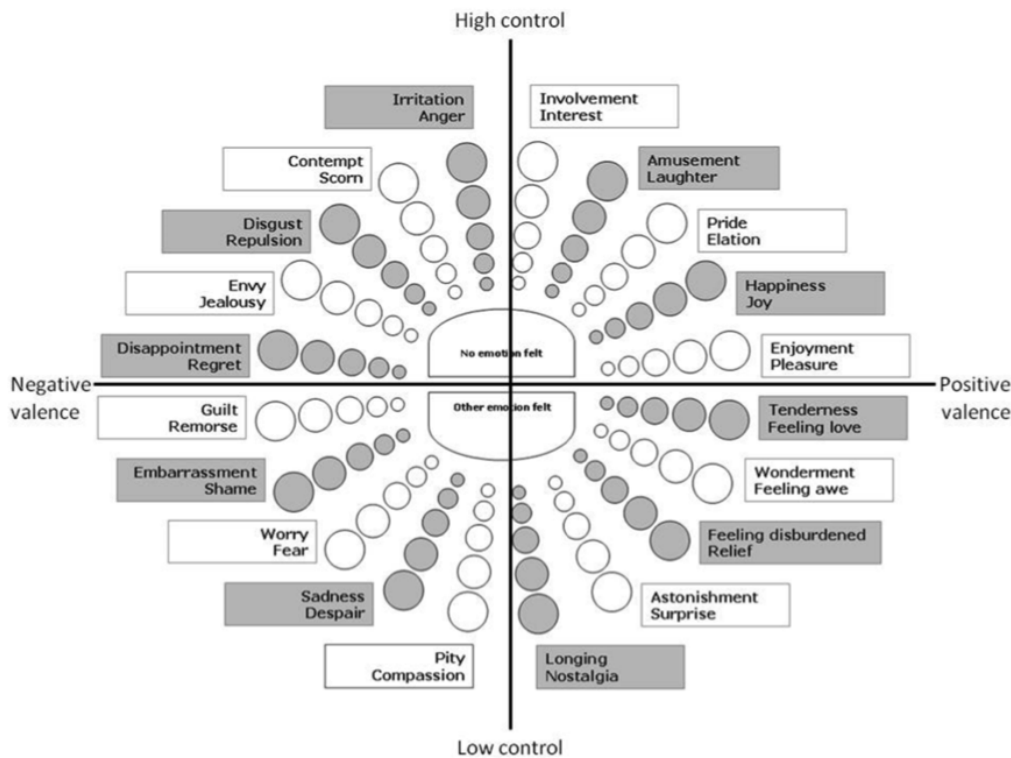


Figure 3.4: geneva-emotion-wheel[62]

3.1.5 ABC-Model by Albert Ellis

The ABC-Model or ABC Technique, which stands for **activating event**, **belief**, **consequences**, helps to understand the reactions of people activating event and stressful circumstances. Sometimes people have developed irrational beliefs which cause negative emotions and extra stress. In order to avoid such negative emotions, a situation can be analyzed in a three column table. The first column contains the Activating Event or objective situation.

The affected person records the actual event which leads to the negative emotion. The second column contains the belief. The affected person records the negative feelings which are caused by the Activating Event. For instance, anger, sorrow, anxiety, etc. The belief acts as a bridge (shown in figure:3.5) between the situation and the distressing feelings if this bridge is interpreted unrealistically an irrational belief system got discovered, which cause the consequences.[14]

For Example:

- (A) Activating Event: A person stuck in traffic jam and arrived at a meeting with a friend two hours late.
- (B) Belief: The person believes that the friend thinks: "why wouldn't he call and let me know he'd be late." He has to get sick of hanging out with me.
- (C) Consequences: I thought we were good friends but I guess that's over now.

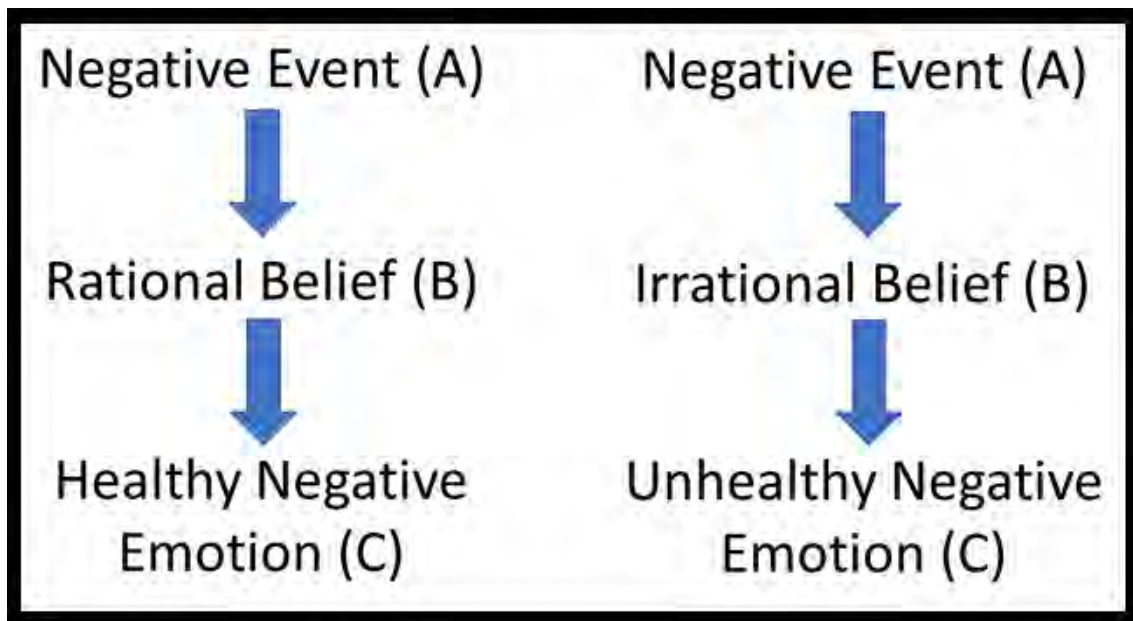


Figure 3.5: ABC-Model[14]

3.2 How to track an emotion?

Track emotions afford sensors like cameras which collecting data about human conditions like facial expressions. In order to make sense out of these collected data a neural network which is trained for facial-expressions can make sense out of the data.[79]

An example of an emotion tracking device is the iPhone X with its TrueDepth camera, a combination out of a front-facing projector which is projects 30,000 dots of light in the invisible infrared spectrum and an IR-Camera is making a picture to track where the dots land in 3D space. With this method, the camera creates a precise 3d model of a face. These models are used for Bio-metrics authentication which is using as stated in 3.2.2Biometrics to distinct between facial expressions and different faces. This technology is Apple using for its face ID.[23]

The advantage of using cameras as a non-contact measurement sensor is that more different data types can be tracked at the same time. For instance, facial expressions and blood flow (e.g 3.2.2 Biometrics) or Body language (3.2.1 Body language). Pulsating blood flow creates a thermal signal (see 3.6) on a superficial vessel which can be tracked by an IR camera. This can be used in order to measure the stress level of a person.

In "IR Remote Sensing to Measure Human Being Stress Level"[11], Brioschi, Marcos and Matias, Jorge and Teixeira, Jacobsen and Viriato, Jose showed that IR signals enable a 96.3 percent success rate in stress level classification compared to Electro-Cardio-Graphy pulse measurements, breathing recordings and classics stress / emotional physiological scales. This method provides bio-metric and psychophysiological parameters for the detection of computational psychology (3.3 Artifi-

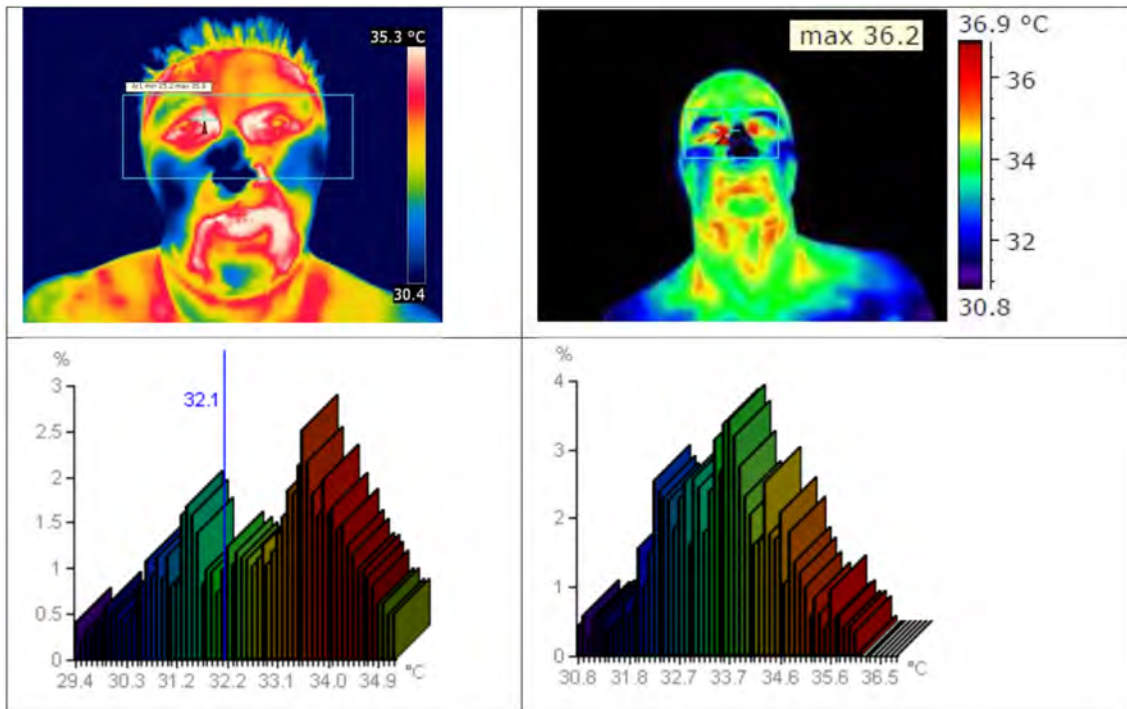


Figure 3.6: Thermal imaging comparison between two different stressed faces and different core temperature [11]

cial Intelligence).

3.2.1 Body language

Body language can be described as nonverbal signals such as facial expressions and body movements. It is essential to pay attention to other indications such as the context in order to interpret body language. There is a wide range of body language, but the most important is facial expressions. For example, facial expression can express happiness, sadness, anger, surprise, disgust, fear, confusion, excitement, desire, contempt.[32]

The facial expression of anger is a universal facial expression, which means this expression will be the same across all cultures. The emotion anger is a response to situations that get perceived by a person irritating, frustrating, or unpleasant. To some extent anger can escalate into acts of aggression.[22]

Some of the facial expression features of anger are (shown in figure: 3.7) lowered eyebrows, squeezed together in the form of a "v" with tight and straight eyelids. The eyes are intensively staring through the lowered eyebrows in the direction of the anger source. The nostrils get flared and wrinkles appear. The mouth and the lips are closed and tight straight or puckered, if not in yelling position. The jaws can be clenched and teeth get pressed together.[22][24]



Figure 3.7: Face Expression Anger[22]

3.2.2 Biometrics

Biometrics comes from bio and metric, meaning biological measurements. This refers to all processes of person recognition, authentication, and identification based on certain physical or behavioral characteristics. For example, fingerprint technology, measurement of facial expression, patterns of veins and walking behaviour.[70]

3.3 Artificial Intelligence

Most progress was made in AI in Artificial narrow intelligent (ANI) and Machine Learning techniques, which only solves specific problems like the processing of natural languages. Unlike, the most common vision of AI mirrors a “Artificial General Intelligence (AGI), which is often considered as AI, should be capable to solve more general problems in the same way as humans do. "Many researchers consider this to be decades away from becoming reality"[4].

The current hype about AI is resulting in advanced development in the field of Deep-Learning (DL), which is a further development of Neural Network (NN). DL is the concept of creating a recreation of the interaction of neurons interacting in the human brain, into a machine. Normal NN's only have 3 - 5 layers and dozens of neurons, while DL networks may have 10 or more profound layers of neuronally simulated interconnections, with neurons numbers simulated in millions.[4] This

makes it possible for an AI or ANI to do reasoning.

What is AI?

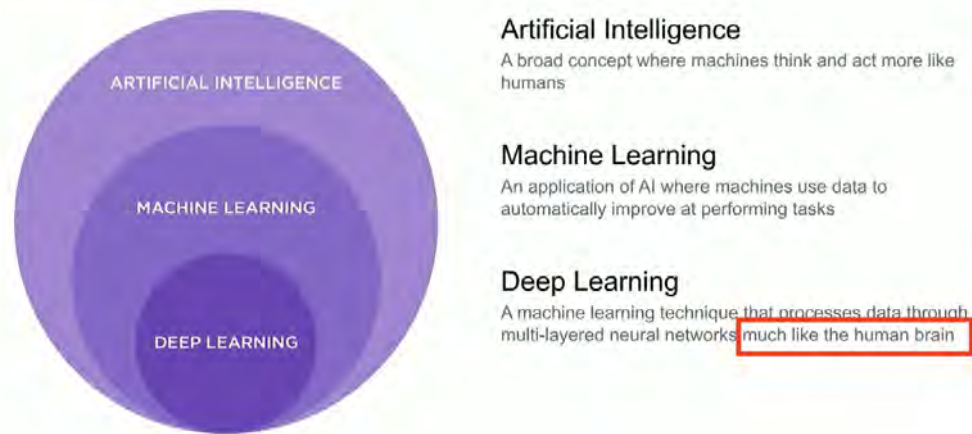


Figure 3.8: Real 2018 slide from a real A.I. unicorn: gotta love the human brain metaphor.[34]

3.4 Sensor Fusion

Car sensors are good at sensing one aspect but bad in another. Cameras, for example, are good for reading signs, detecting cyclists and other cars, but bad for measuring distances. The lidar sensor is good for estimating a position but bad for estimating speed, the Radar sensor is good in return. Sensors have advantages and disadvantages, sensor fusion uses all the sensor advantages to create a precise understanding of the environment.[54]

3.5 Interfaces

Interfaces are a way of controlling a system by giving input over an interface. Don Norman said in 1990: “The real problem with the interface is that it is an interface. Interfaces get in the way. I don’t want to focus my energies on an interface. I want to focus on the job. I don’t want to think of myself as using a computer, I want to think of myself as doing my job.”[40, p.210] The disadvantage of interfaces is that users need to learn them first to achieve their goals.

3.5.1 Non - Visual User Interaction

The world will be moving towards an environment with computer applications that constantly require our attention but more calmer, and with less obtrusive interaction than nowadays. Mark Weiser called this concept “Calm Computing”[68], in

"The coming age of calm technology", he argues that Calm Computing is able to sense the world around the users and learns from the interactions with its user (3.5.2 Ubiquitous computing).

This relatively new way of human-computer interaction without or minimal use of graphical user interactions brings interfaces to the essence of User Experience. It's called non - visual user interaction or short no-UI. To use no-UI software and hardware sensors linked with AI convert the interaction between the user and the users computing devices. These interactions with so-called "Multimodal Interfaces" are used with simultaneous inputs of sounds, speech, gesture, and more. A degree of intelligence is needed to interpret the physical and gestural interaction of users or to determine the best way of displaying information. After the interaction with a user, the outcome gets feed into the system back, helping the system to learn from the process of being used. Finally, in order to design for No-UI three Building Blocks are necessary: observations — sensing and analyze the user, external knowledge — know its user, intelligence — make assumptions depending on knowledge and observations.[44]

3.5.2 Ubiquitous computing

Mark Weiser, a researcher at Xerox PARC, published an article (in 1991) about "Ubiquitous Computing"[67]. Ubiquitous Computing was a vision about computers getting invisible in the future because they moving into the background and operating in the periphery of the user's attention. Further, in this world of Ubiquitous Computing, computers are constantly in need of information.[44]

3.6 Gamification

Gamification comes from the gaming industry and describes a strategy to change behaviors in non-game situations. This strategy follows principles such as mechanics that include goals, rules, and rewards. Further, dynamics that determine how a player performs the mechanics and emotions that provoke how a player feels towards the gamified experience. The reason why gamification works applies to motivational drivers that encourage repetition of behaviors with positive and negative reinforcements. [51] Moreover, motivational drivers releases endorphins in human body that improves memory and learning abilities.[12] An example of gamification and cars is the Nissan Leaf, which has the function in order to get drivers to drive more ecologically friendly, drivers can collect points with driving ecologically friendly, and can share these points on Facebook in order to compete with others.

3.7 Design Theory

Design theory refers to the understanding of design methodology, design frameworks and the strategies to make use of them. Design methodology refers to appropriate strategies in the design process to solve a specific problem within this aspect of the

design process. The following subsections consider Design Thinking (3.7.1 Design Thinking), a design methodology approach to solve problems and Activity-Centered Design (3.7.2 Activity Centered Design), a framework which can visualize where design decisions can be made.

3.7.1 Design Thinking

Design Thinking takes care of the project process, an approach that provides a solution to identify what desirable users really need. It consists of 5 stages (shown in figure:3.9), namely: Empathize, Define, Ideate, Prototype, and Test. The Empathize Stage is about gaining empathy and understanding of the problem that should be solved. In the Define stage the problem Statement is defined. The problem statement is defined by the findings from the empathy stage that are collected, analyzed and sorted into a well - defined problem statement, which in return helps to create possible solutions in the ideation stage to solve the problem statement.

The ideation stage is based on the problem statement and the understanding of the users and their needs, ideas can be generated to identify new solutions to the problem statement. Prototyping is an experimental stage, the aim is to identify the best possible solution to the defined problem. A number of low-cost, scaled-down versions of the solution are produced and tested to explore problem solutions. Finally, the constraints of the solution and the problems that occur will be better understood. The Test stage should identify the best solutions or prototype in order to iterate or implement.[72] It is very often in these steps that a design fails and new insights lead to a redesign that needs to be re-tested (shown in figure:3.9).

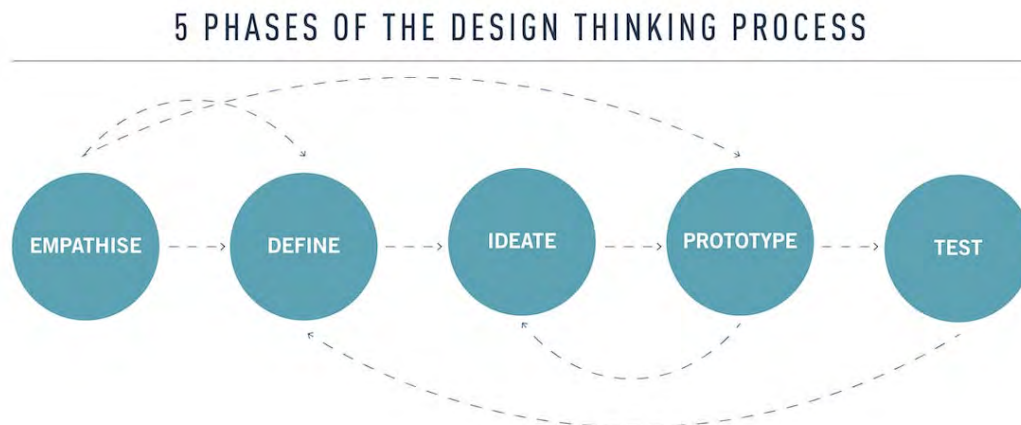


Figure 3.9: What are the five phases of the design thinking process.[69]

3.7.2 Activity Centered Design

Learning how to drive a car is done roughly the same all over the world. This works quite well and can be traced back to the development of a deep understanding of the activities that should be carried out. Activity Centred Design (ACD) focuses on

activities which needs to be performed. A clear distinction must be made between activities and tasks in order to understand ACD (shown in figure:3.10), because activities are composed of tasks, tasks are composed of actions, and actions are composed of operations. ACD combines human understanding with a deep understanding of technology, tools, and the reasons for human activities.[45]

ACTIVITY CENTERED DESIGN

The Activity Centered Design model is an X-Ray into the social and technical workings of an activity. It considers the broader system beyond a single user.

The model is an interconnected lattice with a node for each element. Considering the specifics of these nodes over time is key to developing insight. Read more at dermotholmes.com.

ACTIVITY	WHAT? Listen to music while driving.
MOTIVATION	WHY? Boredom, mood, social norms.
OUTCOME or GOAL	DESIRED STATE Appropriate music is playing.
OBJECT or RECEIVER	WHAT IS OBSERVED? The Car.
SUBJECT or CREATOR	WHO IS DOING THE ACTIVITY? Driver, Passengers
COMMUNITY	WHO ELSE? Radio station, other drivers
DIVISION OF LABOUR	WHO DOES WHAT? Passengers may also operate radio.
RULES & RITUALS	REQUIREMENTS, SOCIAL NORMS Go to favourite channel first. Polite to ask passengers for input. Minimal distraction to operate.
TOOLS & ARTIFACTS	THINGS Interface (shared with GPS) Interface may be bluetooth tablet

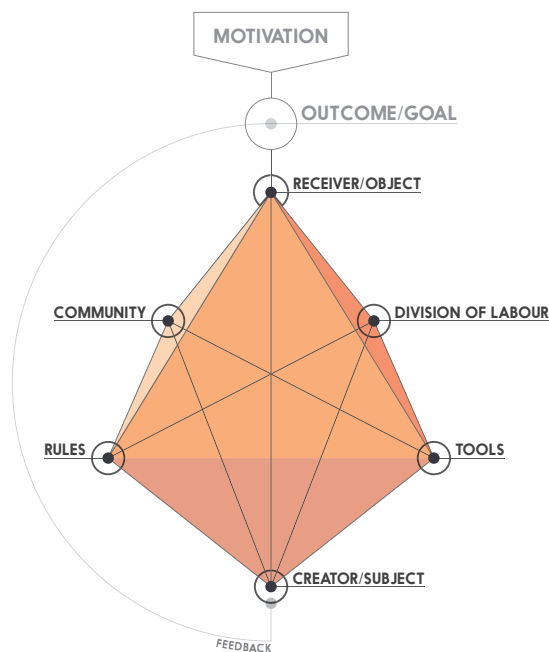


Figure 3.10: Activity design poster [6]

3.8 The Automotive industry

The following subsection is about topics in the automotive industry which are related to safety and artificial intelligence.

3.8.1 EU law for car safety 2022

The EU Commission has ruled out new features which will be mandatory on all new cars from 2022. These new rules include new advanced safety features which will reduce the number of accidents in traffic.

The EU institutions have agreed on a new General Safety Regulation for 2022, with new safety technologies that will be mandatory in European vehicles. This includes according to the European Commission [19] the following features (shown in figure:3.11 represents the features in a graph):

1. Advanced emergency braking (cars, vans)
2. Alcohol interlock installation facilitation (cars, vans, trucks, buses)
3. Drowsiness and attention detection (cars, vans, trucks, buses)
4. Distraction recognition / prevention (cars, vans, trucks, buses)
5. Event (accident) data recorder (cars, vans, trucks, buses)
6. Emergency stop signal (cars, vans, trucks, buses)
7. Full-width frontal occupant protection crash test - improved seat belts (cars and vans)
8. Head impact zone enlargement for pedestrians and cyclists -safety glass in case of a crash (cars and vans)
9. Intelligent speed assistance (cars, vans, trucks, buses)
10. Lane keeping assist (cars, vans)
11. Pole side-impact occupant protection (cars, vans)
12. Reversing camera or detection system (cars, vans, trucks, buses)
13. Tyre pressure monitoring system (vans, trucks, buses)
14. Vulnerable road user detection and warning on front and side of the vehicle (trucks and buses)
15. Vulnerable road user improved direct vision from driver's position (trucks and buses)

Most of these features provide a camera outside and inside the car. The cameras on the outside of the car are responsible for observing the surroundings and make sense out of it. The camera inside observes the behavior of the driver, for example, to use Drowsiness and attention detection and distraction recognition/prevention.

3.8.2 Levels of Autonomous driving

SAE International (Society of Automotive Engineers) published the definition of autonomous Driving (AD) in 2018 in "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles"[35]. This section describes the AD in 6 levels of Autonomy, from level 0 with no autonomy to full autonomy, level 5 (shown in figure: 3.12 shows all levels of AD with description).

Level 2 which describes the current state of 2018/2019 Volvo cars is of particular importance for the Design Process (4 Design Process) because these functionalities are driver assist functions for steering, accelerating/decelerating according to the drivers environment and the driver must still drive and take care of driving tasks.[8] These features are also referred to as Advanced Driver Assistance Systems (ADAS). An ADAS system uses sensors such as cameras and algorithms to steer, accelerate/decelerate, detect road signs and objects on the road, and keep a distance from a front vehicle.

3.8.3 Car Sharing

Carsharing is a membership-based service that is a public service to enhance mobility, according to the Carsharing Association[76]. It also helps members to save money against individual car ownership and supports the goal of decreasing personal



Figure 3.11: New EU safety features for Vehicles in 2022 [19]

car ownership. This, on the other hand, provides all constituencies with affordable access to vehicles and offers access 24 hours a day, 7 days a week.

3.8.4 Life and vehicle costs with good and bad driver behaviour

In November 2015, Chevin Fleet Solutions published an article [20] in which they argue that the best drivers, which indicates a driver which follows the Road Traffic Regulations of the country and a drives in a way to minimize fuel consumption and the emission of carbon dioxide, can reduce the operating costs by more than 12 percent and the worst drivers can easily raise the costs up to more than 13 percent. Chevin Fleet Solutions is an enterprise fleet management software developer

3. Theory

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

Figure 3.12: The Self-Driving Levels according to the SAE[8]

operating in over 180 countries around the world. Chevin Fleet Solution's General Manager, Ken Goldberg, argues that tighter driver controls and emphasis on higher levels of personal responsibility are directly correlated with reduced costs.

Ron Turley from RTA fleet argues in Lanée Mellegard's article "Reduce Costs through Driver Behavior Correction"[65] that driving style can have a significant impact on fuel cost reduction. As a solution he mentioned driver training, smart routing planning and avoiding rush hour or traffic construction can help to reduce costs in fuel consumption.

The article "Five Driver Behaviors that Reduce Cost" from fueleconomy.gov [28] presents high-efficiency driving behaviors. The article focuses on cargo, but three driving behaviors can be adapted to regular car drivers. First, well-planned routing can save time and fuel costs. Regular route planning software takes routes through cities that imply stopping on traffic lights or cross sections, causing extra fuel consumption compared to highways. Furthermore, avoiding construction, road repairs, street closures for events, bursting pipes, reducing driving errors and making driving less vulnerable to driving errors. It is therefore important to take into account feedback on the route from drivers to experience when it comes to route planning. Second, planning for right turns. Take a right turn instead of a left turn if possible. A left turn may interrupt driving flow in stopping and waiting for traffic from the opposite side. Third, steady speed or under speed can increase fuel consumption efficiency in a metropolitan area. The slow driver, on the other hand, has long-lasting

equipment than aggressive and fast driving. According to the U.S. Department of Energy[28] "aggressive driving can lower gas mileage between 15 percent to 30 percent at highway speeds and between 10 percent to 40 percent in stop-and-go traffic."

3.9 Data Privacy

Artificial Intelligence (3.3 Artificial Intelligence) is using data created by people which is in terms of data privacy a problem. This is a problem in terms of ethical consideration and the EU Law General Data Protection Regulation (GDPR). GDPR is defining the duties of the data controller and the rights of the data subject when personal data get processed.

In order to use AI with Data Privacy, the Norwegian Data Protection Authority has published a report called "Artificial Intelligence and Privacy"[81], in January 2018. This report proposes in terms of AI and data privacy tools and methods for good data protection in AI. The paper recommends different methods to reduce the need for training data, methods to protect privacy without reducing the database, and methods to avoid the black box issue. Avoiding the black-box issue is essential because the scheme must be editable in order to correct mistakes in a neural network in case of misinterpretation of training information.

3.10 Literature Review

Method Description: *The literature review is a critical essay that summarizes and evaluates the literature on a specific topic. Summarize, in terms of results or claims from prior research efforts on the topic. Finally, the literature review concludes how accurate and complete a literature knowledge is, and judges what is right or wrong and what is inconclusive or missing. According to Jeffrey W. Knopf in its article "Doing a Literature Review" mentioned 5 benefits from a literature review: It can give an overview of a literature that the reader does not know, it can reveal what has been done well already, it can give the researcher new ideas that can be used in their own research, it can help the researcher to determine where the current research problems or flaws lie, it can enable the researcher to place their own research in a larger context so that new conclusions can be drawn from the research of the reviewers.*[38]

At the start of the design process, the author focused on the literature review to investigate the relationship between emotions and driving.

The content of the investigated studies mainly focuses on the role of emotions and their negative effects on driving and safety. During the literature review, it became clear that research on positive emotions lacks empirical evidence and needs further research [49]. Moreover, it becomes evidential from the literature review, that the most frequently studied emotions are: anger and sadness, and less considered were

happiness and joy, surprise and fear.[49][36]

Anger and sadness according to the Geneva Emotion Wheel (3.1.3 Geneva Emotion Wheel), are both in the category of negative valence but, distinctive arousal. Anger is high-arousal and sadness low-arousal (3.1.4 Emotional Dimensions). For example, when it comes to memories from situations with anger, high-arousal emotional memories last longer, whereas memories for non-arousing events are more likely to dismembered.[39]

This explains a phenomenon called the "weapon focusing effects" in which crime witnesses often remember a crime weapon, but don't remember any details, such as how to identify the perpetrator. High-arousal caused by fear let witnesses fall into a hyper-focus on the weapon.[60] In relation to driving this means if a person gets angry while driving, the cognitive ability's of the drivers are affected.

Driving requires different levels of cognitive tasks, such as attention, understanding, projection, decision making, and selection of actions with regard to Emotional experiences [36]. In addition, emotional experiences are characterized by "physiological changes," "behavioral changes" and "specific state of mind" [49].

The created insights about emotions and driving, was investigated by different Methodology, such as: questionnaires[49], self-reports[49], emotional inductions[49], and driving simulations [49][36]. According to the research paper of Jeon[36], emotions got tested in a driving simulators with manipulating driving scenarios and inducing a specific affective state. For this test, 257 young drivers ("M = 184, F = 103, Mean age = 20, Mean driving years = 4.6 years"[36]) were conducted in seven experiments. Jeon[36] is considering according to its research results that, "it can be debatable whether the induced affective states in a driving simulator are equivalent to the affective states in actual driving"[36].

The author presents the findings of two negative emotions in 3.10.1 Anger, stimulus and behavior and 3.10.2 Sadness, Stimulus and Behavior, namely anger and sadness as safety-critical emotions. The results are divided into Stimulus and Behaviour. The literature shows no evidence to make in case of negative emotion evaluation a gender distinction, according to that further development research will be considered in a gender-neutral view.

To summarize, negative emotions affect behavioral drivers depending on the nature of emotion. Negative emotions are highly associated with the driving situation, but negative emotions can be regarded as negative conductor behavior. In the case of anger, angry drivers are more likely to take risks. According to Myounghoon Jeon in "Lessons from Emotional Driving Research", anger produces the most errors (shown in figure: 3.13) while driving. In case of sad drivers have performance degradation in driving, due to rumination and self-focus.[49]

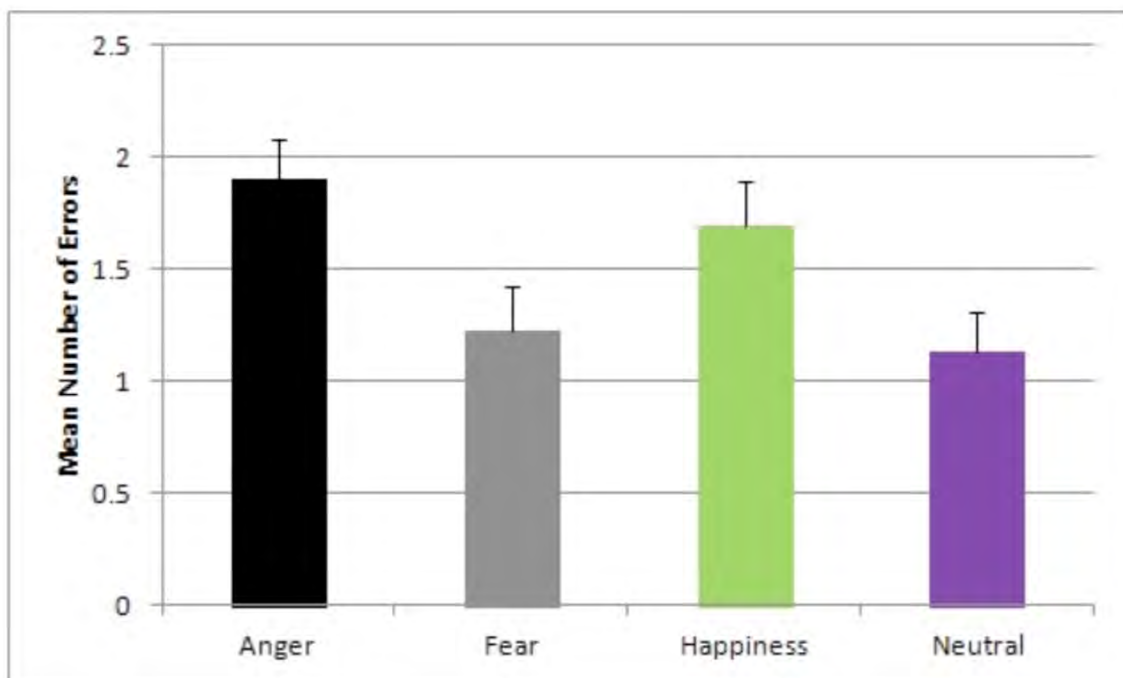


Figure 3.13: Mean number of errors across affective states. Error bars indicate standard error of the mean.[36]

3.10.1 Anger, stimulus and behavior

According to the Cambridge dictionary, the definition of the **mental state of Anger** is [5]: "anger is a strong feeling that makes you want to hurt someone or be unpleasant because of something unfair or unkind that happened." In addition, Aristotle's, Paul Eckman, and Robert Plutchik, describes anger as the opposite of being calm (see 3.1.1 Basic Emotions).

Based on the information available, it was found that anger is the second most frequently occurring emotion [49]. Research has shown that our various cognitive functions, like attention, reasoning, , and decision-making are impaired by anger [50]. Anger **stimulus** may be caused by road or traffic situations, for example:

1. Heavy traffic [49] [50]
2. Hostile stimuli such as horn-honking [49] [50]
3. Driver's personality [49]
4. Forced to reducing speed [49]
5. Consequence of traffic violations and unsafe driving.[49]

The drivers **behavior** changes after anger is stimulated.

Changes can be characterized by **physiological changes**, such as:

1. Increase of heart rate [49] [17]
2. Blood pressure reactivity [49]
3. Recognizable facial expressions [49]
4. Recognizable postures [49]

5. Muscle tension generally in specific places like the shoulders or jaws [17]

In addition, **behavioral changes** can be described in changes, such as:

1. Increasing acceleration[49]
2. Driving over speed limit / driving maximum speedlimit) [49][36][17]
3. Throttle pressure[49]
4. Increasing steering wheel use[49]
5. Increased overall driving errors[36]
6. Lane deviation [36]
7. Lower safety level (tendencies to take risks and be aggressive) [36][49]
8. No indications that angry driver might not be consciously aware of their plausible risk. [36]
9. Tending to traffic violation (“road rage”)[49]
10. An angry driver with "the illusion of control" is more likely to drive in a risky and aggressive manner[50]
11. Honking, yelling, and showing hostile gestures, tailgating or harmful manoeuvre, ultimately leaving the car for verbal attacks or physical violence due to the inability to communicate differently[50][17]
12. judgmental/ disbelieving thinking (Disbelief in how others drive, and how they should not be allowed to drive)[17]
13. revengeful/retaliatory thinking (Thoughts about the behaviors needed to exact revenge)[17]
14. pejorative labeling/verbally aggressive thinking (very denigrating, derogative, often obscene judgments about other drivers and verbally aggressive behaviors such as shouting obscenities to another driver)[17]
15. physically aggressive thinking (The thoughts of harming others and the behaviors needed to do so, such as running the person off the road)[17]

3.10.2 Sadness, Stimulus and Behavior

According to the Cambridge dictionary[53], the definition of the **mental state of sadness** is: "the feeling of being sad or unhappy".

Sadness, while driving is not necessarily caused by road or traffic situations. The **stimulus** for being sad can occur before or during driving and can be characterized such as:

1. Facing a negative event [49]
2. Feeling of lasting guilt[49]
3. Low self-esteem [49]
4. Emotional disorder[49]
5. Depression [49]

The typical **behavior** changes while experiencing sadness can be described in in **physiological changes**, such as:

1. Concentration problems [49]
2. Can be more or less intensive [49]
3. Crying [49]
4. Shouting [49]

5. Could affect a driver for years if its origin is in a dramatic event [49]

In addition, **behavioral changes** can be described in changes, such as:

1. Performance disturbance [49]
2. Rapid oscillations between other emotions (anger, nostalgia, and happiness) possible [49]
3. Degradation of controlled processing due to self-focus and ruminations, fixation on their problems [49]
4. Reactions and feelings [49]
5. Slowness in disengaging attention [49]
6. Slower steering reaction times [49][36]
7. Lane departure [36]

3.10.3 Important Findings with focused on Anger and driving

Findings — Literature Review, (3.10 Literature Review)

- *Physical changes from anger*
 - high heart rate,
 - high blood pressure
 - recognizable face expression
 - recognizable postures
 - Illusion of self control
- *Cognitive changes from anger*
 - Anger lowered safety level
 - When angry people drive risky they are aware that they take risks.
 - Anger let people make decisions without rationality
 - Angry drivers have an increasing steering wheel use
 - Angry driver doing lane deviation
 - Angry driver increasing acceleration
 - Angry driver driving more likely fast
- *Stimuli of anger in traffic*
 - Heavy traffic can cause anger while driving
 - Hostile stimulation like horn honking can cause anger while driving
 - Changing speed all the time can cause anger while driving
 - Traffic violence can cause anger while driving
 - Unsafe driving can cause anger while driving
 - Anger degenerated driving performance in increased overall driving errors
- *Errors in Traffic while being angry*
 - anger increases overall driving errors (errors stated in 5.8 Volvo Intuit in the list **List of Poorly behavior**).
 - Anger degenerated driving performance in over speed, compared to the neutral condition.
 - Anger degenerated driving performance in maximum speed, compared to the neutral condition.
 - Anger degenerated driving performance in lane deviation, compared to the neutral condition.

- Anger degenerated driving performance in aggressive driving behaviors, compared to the neutral condition.

3.11 Summery of Theory

This project considers theories about basic emotions, as well as, in depth, the emotions anger and sadness. In case of anger (3.10.1 Anger, stimulus and behavior) and sadness (3.10.2 Sadness, Stimulus and Behavior) an investigation got to be done about physical changes, cognitive changes, Stimuli, and errors in traffic. The investigation is based on a Literature Review (3.10 Literature Review). Furthermore, different emotion based models got investigated like Geneva Emotion Wheel (3.1.3 Geneva Emotion Wheel) and Plutchik's Wheel of Emotions (3.1.2 Plutchik's Wheel of Emotions).

At the same time the author investigated interfaces (3.5 Interfaces) between human and machines to make emotions computational accessible. For this reason topics such as Body language (3.2.1 Body language), Biometrics (3.2.2 Biometrics), Non - Visual User Interaction (3.5.1 Non - Visual User Interaction), and Ubiquitous computing (3.5.2 Ubiquitous computing) were reviewed.

In order to get an understanding of the car industry, topics like Autonomous driving (3.8.2 3.8.2), Car Sharing (3.8.3 Car Sharing), Life and vehicle costs (3.8.4 Life and vehicle costs with good and bad driver behaviour), and EU law for car safety 2022 (3.8.1 EU law for car safety 2022) were reviewed.

In addition, AI (3.3 Artificial Intelligence) got reviews as a technology which could have great potential in the car industry but got often wrongly understood, what AI can really do.

Finally, design frameworks such as Design Thinking and Activity-Centered Design were reviewed as a manner to structure project-based, solution-based, and user-activity-based to address issues in order to achieve a design idea.

4

Design Process

This chapter represents the design process, including research, framing the problem over exploring possible solutions with high use of design methodology within a design thinking (e.g 3.7.1 Design Thinking) structure.

4.1 Qualitative Research

Method Description: *Qualitative research is primarily concerned with exploratory research and aims to gain an understanding of a topic. Data produced by Qualitative Research comes from a typically small amount of participants with unstructured or semi-structured research techniques such as interviews, focus groups, observation.*

The author considered qualitative research because the subject of emotions and driving is too complex to be encapsulated by a simple yes or no hypothesis. Qualitative research techniques are richer and more insightful in the underlying reasons and patterns within phenomena.

4.1.1 Expert Interviews

Method Description: *Interviews are used to gather qualitative data about a specific topic. There are four different types of interviews: Unstructured-, structured-, semi-structured-, and group interviews. The author decided on this project in order to gather a broad range of qualitative data for a semi-structured interview. The semi-structured interview combines the unstructured and structured interview. The unstructured interview follows a guiding set of topics that make the interview more conversational, rich in data and gives a deeper understanding of the topic. An unstructured interview has an exploratory purpose and open questions or open-ended questions are used that require more than one-word answers. The answers could come from a list, a few sentences, or something longer like a speech, paragraph, or essay. The structured interview aims to be more rigorous and is more formal and impersonal in its implementation. Questions must be logically structured and formulated in brief and clear words. In terms of questions, time and analysis, the structured interview is much easier to control. However, a semi-structured interview means that open and closed questions are used, but also a preconceived guidance script is followed. The method can be performed face to face, by telephone, or as a survey with the interviewees. The method's adaptability is an advantage over other qualitative methods.[48, p.465-469] In contrast, an expert interview follows basically*

the same structure as a regular interview, but it differs in the selection of participants because it interviews experts with special knowledge related to their professions.

In total the author interviewed three different experts within the field. The first, Interview was a "Specialist in Data Analysis" at Volvo cars (5.1.1 Specialist in Data Analysis at Volvo Cars). He is focused on the development of Machine learning applications. The second interview was a "Psychologist, with a focus on behavioral therapy" (5.1.2 Psychologist with focus on behavioural therapy). The Third interview was a "Costumer Researcher at Volvo Cars", and focused on user research (5.1.3 Costumer Researcher at Volvo Cars).

4.1.2 Questionnaire

Method Description: *The questionnaire is a research technique to collect answers to a list of questions written about a specific topic. The main purpose is to gather information in a quantitative or qualitative data format, this depends on the format of the written questions. According to the Business-dictionary [77] a questionnaire: collects appropriate data, make data comparable and amenable to analysis, minimize bias in formulating and asking a question, and to make questions engaging and varied. For this project, the Questionnaire is used to collect emotional data while driving from the actual users and to obtain insides from other research papers about the truths of emotional driving. The author structured the questionnaire into open-ended questions and Likert scales. Open-ended questions provide a text field in which the participant can write an answer as long as he wants. The Likert Scale is a rating scale that is a measurement technique for interviews, questionnaires, and surveys to measure peoples ' attitudes to a specific topic.*

The questionnaire was conducted with 57 participants from Sweden, Germany, Switzerland, and Australia in an early stage of the project. A questionnaire is a greater method because it a sure-fire success. When the questionnaire is posted or sent to individuals, the author can simultaneously take other significant measures in the study stage.

The questionnaire was created in "Google Forms" and got sent by email to specific people like friends, family, people inside Volvo cars and got published on social media platforms such as Facebook and LinkedIn. It consists of 22 Questions regarding emotions while driving. The structure of the Questioner was divided into different first and second level emotions with a Likert-scale question and an open-ended question. The Likert-scale questions were used to get an idea about how aware people are about emotions while driving. The awareness was scaled between attentive, neutral, and inattentive. The results were a self-reported perspective of the emotions while driving of the participants and the final result was more likely a neutral value of all tested emotions. Which can mean the people are less aware of emotions while driving, the question affords high cognitive workload to answer, or people do not have an option to rate emotions while driving. The result from the Likert-scale was ambiguity which makes the result not valid for further research. The open-ended

questions gave an indication about peoples awareness of emotional driving and if people have countermeasures to avoid emotional driving. The results of the open-ended questions where a few insights and needs about the user and some scenario where emotional driving can occur. These results will be checked back in a further step (stated in 4.3 In-Depth Interview)to prove the reliability.

4.2 Data gathering

The following subsections contains the findings from 3.10 Literature Review,4.1.1 Expert Interviews and 4.1.2 Questionnaire. Driving in sadness can in some cases drawn back to as mentioned in 3.10.2 Sadness, Stimulus and Behavior in low self-esteem, Emotional disorder, Depression[49]. These issues need more research and the author had to focus on one of the two reviewed emotions (anger and sadness) due to time constraints.

In case of anger it got investigated in 3.2.1 Body language that anger is a universal facial expression. This means that anger has a high generalizability across cultures. The author focused on anger as a conclusion.

An investigation is that, according to the research, anger and stress have a connection (shown in figure: 5.1), which is a valuable insight for further steps in this project.

In addition the findings got analysed and structured into 3.10.3 Important Findings with focused on Anger and driving as a result. Furthermore the findings, 4.2.1 The User, and 4.2.2 The User Needs got transformed into an Affinity Diagram (4.2.3 Affinity Diagram).

4.2.1 The User

This section describes the user based on sociological development and generation trends which got discovered in the 5.1.3 Costumer Researcher at Volvo Cars. A user is a person who is using a car to commute or to travel to a lot of different places sometimes during the day. In case of using a car the car not necessary has to be the users own car. In Addition, the user is using public transport and car sharing on how it is suitable for him. A user is a person who is attached to freedom of choice and less likely to planing for a far future.

The user belongs to the age group, described as Millennials (also known as Generation Y and born between 1980 and 2000), who grew up with electronics, the Internet and online social communities, spending 18 hours a week on their smartphone and likely to be college graduates.[73]

A user is a person who moved to a bigger city where his job is located. The user lives in areas where space is costly. Rents are high and it's hard to get parking space. Cars in big cities mean commitment, because of parking place have to be rented out and insurances have to be paid. The user is more likely to avoid such

commitments.

The user can afford a personal car, but a car's cost would limit its quality of life, which makes him believe he couldn't afford a car.

4.2.2 The User Needs

The user needs were discovered during 5.1.3 Customer Researcher at Volvo Cars. The User needs are stated in 5 Results in the section 5.2 The User Needs in Volvo cars

4.2.3 Affinity Diagram

Method Description: *The affinity diagram is a flexible and easy-to-use method that allows the use of pos-it notes. First, data and ideas generated by research and brainstorming are transferred to handwritten post-it notes, only one information per note. In a next step, all the notes will be gathered on a wall to make them visible. Finally, the notes will be discussed and labeled in order to organize and structure them into themes. This can also be done with or without a facilitator. The method's goal is to generate large amounts of information that will be organized in a useful order to frame a problem or need.*[43, p.12-13]

The Affinity Diagram (shown in figure: 4.1) gathered all the data together from the current research, such as Literature Review (3.10 Literature Review) and Qualitative Research (e.g 4.1 Qualitative Research). This enables the author gain an overview of the present phase of the studies and enables quicker access to significant insides in further steps.

The information was structured into 7 categories: Negative Emotions, Emotional Behavior, Impact on driving, emotional source, Task while driving, control emotions, AI & Future. The 7 category helps to structure further development of the project.

4.3 In-Depth Interview

Method Description: *In-depth interviews are conducted with a target group (4.2.1 The User) of people within the topic. The in In-depth interviews helps to get a deeper understanding of the target group perspectives, attitude, problems, needs, ideas, or environment. In-depth interviews are structured as regular interviews or expert interviews (4.1.1 Expert Interviews) in a semi-structured or unstructured manner, but most commonly structured in a semi-structured. In-depth interviews are arranged in a "funnel" way, general and broad at the beginning, and more specific and detailed at the end. Its be carried online or by telephone but it is best practice in a face to face atmosphere because researchers are able to gain extra information by observing body language, or can co-create simple scribbles, mind maps, personas, journey maps,*

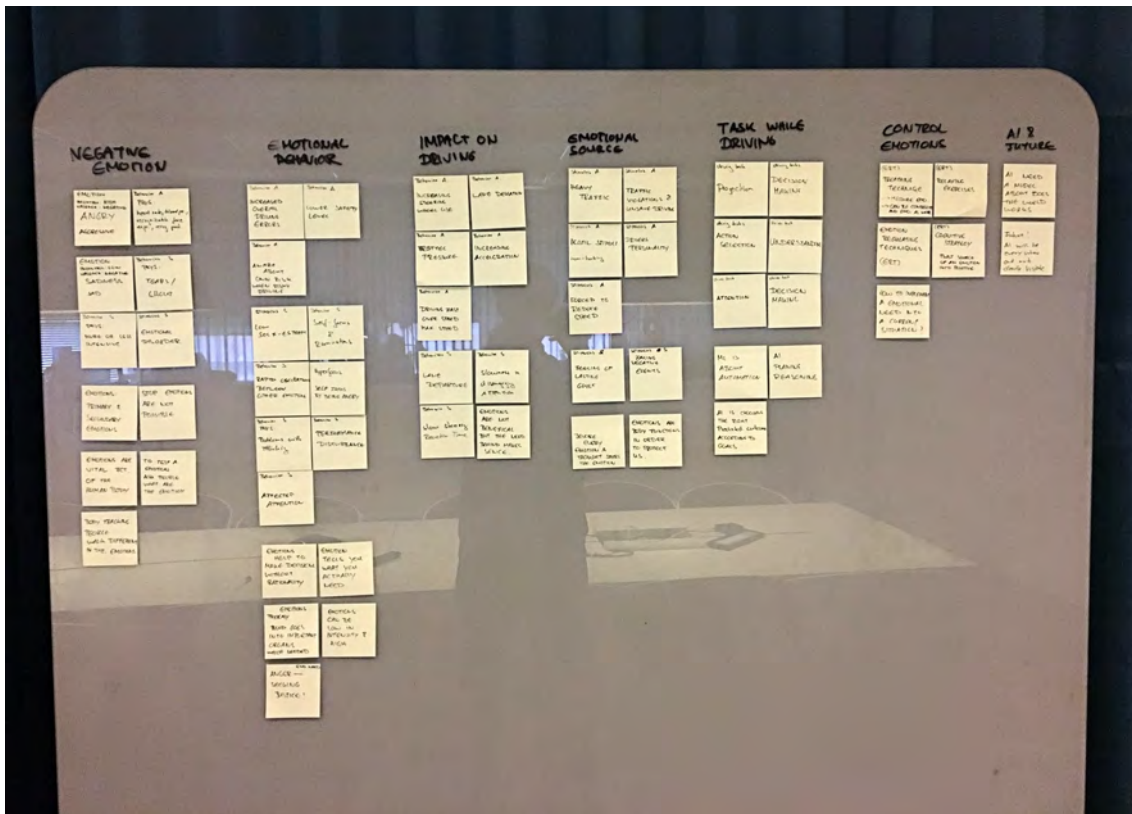


Figure 4.1: Affinity diagram about Expert interviews, Literature review and questionnaires results

etc. with the user.[64]

The Author expects from the In-depth Interview to investigate which findings from 4.2 Data gathering and 4.2.3 Affinity Diagram created by literature review (3.10 Literature Review), Questionnaire (4.1.2 Questionnaire) and the Expert Interview (4.1.1 Expert Interviews) are coherent with the user (4.2.1 The User), user's activities (3.7.2 Activity Centered Design) and needs (4.2.2 The User Needs).

Before the actual In-Depth Interview could be carried out the author had to prepare the In-Depth Interview and test it in a pilot study. An In-Depth Interview offers rich and detailed information in understanding people's experiences, but for inexperienced researcher to adequately perform in an In-Depth Interview can be difficult. In order not to waste valuable time and resources of people, piloting an in-depth interview is an integral aspect and useful in the process of conducting qualitative research as it highlights the major study's improvisation. Improvisation to interview questions and formulations accurately and to indicate useful and unnecessary questions to shorten the interview length that saves participant's cognitive workload, and leads to more valuable answers.

The pilot study was conducted in 30 minutes with 3 Volvo car employees from the Volvo User Experience Design Studio. The questions were structured with a closed-

ended questions aiming on the findings (3.10 Literature Review, 4.1.2 Questionnaire, and 4.1.1 Expert Interviews) and as a follow up a open-ended questions based on the method "5 Whys". The method of 5 Whys is a tool to get deeper insights and to find example scenarios from the participant. In order to ask the same question 5 times over and over again. The participant gets forced to give a more possible answer to the question [2].

The proper In-Depth Interview (4.3 In-Depth Interview) was conducted with 7 people from Sweden, Switzerland, and Germany. The participants were in the age between 26 to 31 years old (3 female and 4 male) and driving experience between 5 until 15 years. The interviews took approximately 2 hours each.

As one finding of the In-depth Interview, people who experience anger while driving tending to risky maneuvers, consisting of more steering, lane deviation, acceleration, and speeding. That indicates a lack of knowing how to behave while driving and being angry. Furthermore, According to Siegman, Aron Wolfe and Smith, Timothy W. in the book "Anger, hostility, and the heart"[55] the authors claim that "With the best intentions to remain calm, it is very difficult to interact with an angry person without becoming angry oneself". Reflecting, to driving in traffic with at least one person who becomes angry, this could lead to drivers making other drivers angry.

4.4 The Problem Statement

Method Description: *The Problem Statement is a method which is following a User-centered approach to frame a problem to a specific user. Furthermore, it includes ways to formulate (4.4.1 Point of View) and creating a direction to solve the problem (4.4.2 How might we ...?.[59]*

4.4.1 Point of View

Method Description: *Point of View (POV) is a method used to define the design challenge to inform a problem statement. The method is usually used in the defining stage (Stage 2) of the Design Thinking process. It sets the overall tone of the following activities. POV builds on a profound understanding of user needs and the key insights from research and fieldwork in the stage of empathy (stage 1). However, it is important that a POV does not contain specific solutions or how to meet user needs in order to design for service, experience or product.[18]*

The POV got created out of the results from 4.3 In-Depth Interview and the 4.2Data gathering. In a second step, the POV as stated in 5.4 Point of View about Angry Driving got created, which is a based on anger and driving filtered version of the original POV (A.2 In-Depth Interview result).

4.4.2 How might we ...?

Method Description: *"How might we" is a follow-up method used to generate ideas from the POV. In order to generate ideas, the author has to ask questions in the structure of "How Might We" or "in what ways might we", which leads to directions of ideas or solutions.[18]*

- How might we design for angry Drivers?
- How might we design for unexpected situations, so that the driver not get stressed?
- How might we design for avoiding Anger and stress
- How might we design for Time pressure?
- How might we design for stressed drivers?
- How might we design for Angry driving, so that is results in no traffic error behavior?
- How might we design for preventing from bad behavior from Anger and Stress?
- How might we design for Angry driving, so that thinking less rationally is not dangerous?
- How might we design for speeding?
- How might we design for risky maneuvers?
- How might we design for lane deviation?
- How might we design to keep distance to the car in the front?
- How might we design for data transparency?
- How might we design for support, which not feels like losing control?
- How might we design for educating/reflecting about anger and stress behavior in traffic?
- How might we design for motivating to behave in traffic to not make other angry and stay safe?
- How might we design for not making other drivers angry?

4.5 Requirements

Method Description: *Requirements are statements about what should or should be done by an intended product or service. In order to write requirements, the wording of a requirement has to be as clear and easy to understand as possible and states something that is necessary, verifiable, and achievable. Two types of requirements can be distinct: functional requirements and non-functional requirements. According to Preece, Jenny and Rogers, Yvonne and Sharp, Helen in "Interaction design: beyond human-computer interaction"[48, p.692-712] non-functional requirements are: "look and feel requirements, usability and humanity requirements, performance requirements, operational and environmental requirements, maintainability and support requirements, security requirements, cultural and political requirements, legal requirements". Functional requirements, on the other hand, describe the operations and activities that a system must be able to perform.*

The Requirements which are stated in 5.5.1 Design Requirements are in a living document, which means that new requirements have been created and been removed over time in the design process.

4.6 Ideation

In the ideation phase, the author uses 4.6.2 Brainstorming to create and explore a wide range of solutions and ideas according to the problem statement (4.4 The Problem Statement) and the requirements (5.5.1 Design Requirements).

4.6.1 Personas

Method Description: *Personas is a user-centered design method that is created by collecting data from qualitative methods such as questioners, interviews, etc. A huge quantity of qualitative data can be abstract and Personas help to capture common behaviors in meaningful and related profiles. These profiles communicate the target group and support designers to design responsibly. [43, p.132-133]*

The persons of this project were created for further development by the underlying data from 4.1 Qualitative Research, 4.2.1 The User, and 4.2.2 The User Needs. The purpose of the personas is to evaluate ideas and solutions from the 4.6.2 Brainstorming. Personas help the author to make precise statements if an idea or solution is relevant in order to find the best possible solution.

The author created a total of 4 persons A.1 Persona 01, A.2 Persona 02, A.3 Persona 03, A.4 Persona 03. The personas are 2 men and 2 women, aged from 21 to 32 years old. The information structure of the persons is organized in "personality in traffic", "goals in driving", "frustration in driving", "technology." With "personality in traffic" the author wants to express different driving behaviors which got found through 4.1 Qualitative Research. These behaviors can be expressed in how safe or risky, how slow or fast, how attentive or attentive, how experienced or inexperienced, how relaxed or stressed, and how calm or angry a person is behaving in traffic. "Goals in driving" express a goal or desired result that want to get achieved with the use of a car. "Frustration in driving" are reports from the 4.3 In-Depth Interview and expresses situations where the personas get stressed or angry in traffic. Technology expresses the knowledge and ability to use technology. Additionally, each person has a quote and a quick description that gives a feeling for the personas' personality.

4.6.2 Brainstorming

Method Description: *Brainstorming is a design method, that fits perfectly into an ideation session. To get the most out of Brainstorming, it is conducted into a group of designers or users and a facilitator that structures the brainstorm session, but it is also completely normal to do brainstorming alone. The purpose of brainstorming is to generate ideas for solving problems. Brainstorming can be done through sketching, writing, and craftsmanship. Basically, everything that helps to*

transport and record ideas can be used.[71]

The author brainstormed ideas with the help of personas (4.6.1 Personas). These personas makes it easier to stay on track while ideating and in addition, help later on for evaluating ideas. The Brainstorming session focused on distinct alternatives, but primarily on a technology that operates seamlessly with vehicles. This implies setting up or preparing a functionality in a smartphone app before approaching the car.

The Ideas from brainstorming

1. **Emotion Mirror:** The emotion mirror is a device that is attached outside the car and can be seen from others. To avoid sharing your own emotion, you try to stay calm.
2. **Proactive ADAS System:** While experiencing anger or stress in connection with traffic misconduct, the driver support system is automatically activated for a limited time.
3. **Virtual Assistance:** If you are misbehaving in traffic or experiencing stress or anger in traffic, a soft voice will start a conversation with you to communicate the misbehavior and calm down the driver.
4. **Emotional Shiftier:** Using cognitive strategies in moments of anger to shift the perspective of drivers to positive emotions.
5. **Emotional Driving Scoring System:** A kind of platform connected to social media that visualized how safe you are driving in traffic. You can be rated as a safe or dangerous driver. The result may or may not be shared.
6. **Quantify Others:** Drivers can rate other drivers while driving, as a result, drivers are willing to behave in order to get a good rating, like a driver equivalent to the 2011 Black Mirror episode Nosedive[10].
7. **Visualize Emotion:** Visualize Emotions makes sense out of emotions in traffic situations, if a person gets stressed or angry in traffic, the system compares the real mental state to the context in which it happens. This helps the system understand where people get stressed or angry and can advise the driver in the future.
8. **Emotional Diary:** The system recognizes if the driver is stressed or angry and marks this location where it occurred on a digitally accessible map. When the map is shared by others, a heat map of emotional critical areas can be created and drivers can plan routes around emotionally critical places.
9. **AI Route planner:** Emotional Diary concept but plus a route planning system that supports you to plans your journeys in a seamless and trouble-free way of avoiding critical emotional roads.

4.6.3 Weighted Matrix

Method Description: The method weighted matrix compares ideas with criteria that need to be considered when making a decision. A matrix-rating-system can be used to compare ideas and criteria. The success criteria (business criteria) weigh the highest weight at the top and the lowest weight at the bottom. The highest weighted criteria are rated with the most points and the lowest with one point. After that, the

ideas will be placed in each column and discussed how well the criteria fit with points from the first to the last criteria. Ultimately, the idea with the most points has the highest value. The decisions are documented in clear, structured ways to ensure that others understand your reasons for making them. The aim of the method is to help a team make complex decisions, especially in cases where there are many alternatives and many criteria of varying importance to consider.[43, p.202-203]

In order to fulfill the method (A.3 Weighted Matrix Tables), criteria got formulated from 4.2.2 The User Needs, 4.4.2 How might we ...? and ordered from important to less important. Important criteria were rated by 3 points, less important was rated by 1 point and everything in between was rated by 2 points. Finally, the ideas from Brainstorming 4.6.2 Brainstorming have been compared with the criteria and the 4 ideas with the most points will be used for further development.

Criteria for the Weighted Matrix Method

1. Avoiding bad traffic behavior / style
2. Driver Support to minimize driving errors
3. Motivation for good behavior in traffic
4. Avoiding stress
5. Avoiding anger
6. Avoiding time pressure
7. Avoiding unexpected situations
8. Seamless and Trouble-free journey
9. Education for better driving
10. Convenient interactions
11. Not making other drivers angry
12. Intelligence to minimize user's cognitive workload
13. Driver Support with minimal interaction
14. Reflecting on own driving behavior
15. Not feels like losing control
16. User performs effectively

According to the result (A.3 Weighted Matrix Tables) of the Weighted Matrix, the author decided to use the first highest rated ideas (Visualize Emotion, AI Route Planer, Proactive ADAS System, Emotional Diary) for further development. For further development, the Author uses the running title of the project "Volvo intuit".

Intuit by definition of oxford dictionary means [33]: "to know or understand something because of a feeling that you have rather than because of facts or what someone has told you". It should mean Volvo empathize and cares about you and in order to keep track of your emotional state it will that you stay safe and drive safe.

4.6.4 Minimum Viable Concept

Method Description: *Minimum Viable Concept also known as Minimum Viable Product or MVP follows the same idea but focuses on a concept rather than a product. The idea is to reduce a concept to the necessary features. This enables*

prototypes to be created and tests to be carried out as quickly as possible. Quick prototypes and testing generate knowledge for iterative improvements to the concept.[42]

Because of limited time, the MVC was necessary. The author had only a few weeks left in this phase of the project until the final presentation. This forced the author to break the concept down to the most important features. Beyond, an MVC is also an opportunity to define the concept temporarily in a design process that helps to stay on track while prototyping the concept.

After the 4.6.3 Weighted Matrix the whole concept includes Visualize Emotion (4.6.2 Brainstorming idea number 7), AI Route Planer (4.6.2 Brainstorming idea number 9), Proactive ADAS System (4.6.2 Brainstorming idea number 2), Emotional Diary (4.6.2 Brainstorming idea number 8).

The MVC focuses on shared or subscription cars, which according to the current trends, it seems the future car trend (3.8.3 Car Sharing). The concept is reduced to 4 features: **Visualize Emotion** and **AI Route Planer** get fused together to the feature **Preventing**. **Proactive ADAS System** gets defined into the feature **Evasion**. **Emotional Diary** gets split up into the features **Educating/Reflecting**, and **Motivating**. The following table describes the MVC Features of the concept in its functionality:

MVC Features

1. **Preventing** means the user can plan a route in advance to get according to live traffic data and stress/angry heat map the options to choose the most trouble-free journey. In addition, the driver will have a live route overview about this he will face on the route in order to be prepared for the unexpected.
2. **Educating/reflecting** means the driver is getting textual feedback while driving as suggestions for miss-behavior or suggested solutions to stressed/angry situation. Furthermore, the driver is getting a debrief after every driving station in order to reflect on what he is doing great and where he could improve.
3. **Evasion** means to have a support system in case the driver gets angry. This will be a proactive ADAS system which will support the driver while being angry to not misbehave in traffic.
4. **Motivating** means the user stays motivated to behave in traffic because the hours he is behaving is reducing the amount he has to pay for the rental cost. This not only saves the user money but this safe also money for the lessor(/renter) because a good treated car cost less in maintenance over the year.

4.7 Wire-framing

Method Description: *Wire-framing is a low-fidelity approach which is communicating a design but without coding. Wire-frames are limited in content and limited in the use of colors or other visual design elements. The purpose of a wire-frame is to create a user flow and finally a prototype.[48, p.796] A user flow is a set of steps*

4. Design Process

that a user has to take to achieve a goal. This can be done with wireframes or with a final design.

The Wire-frames for Volvo Inuit got created first as a sketch on paper, see figure:4.2).

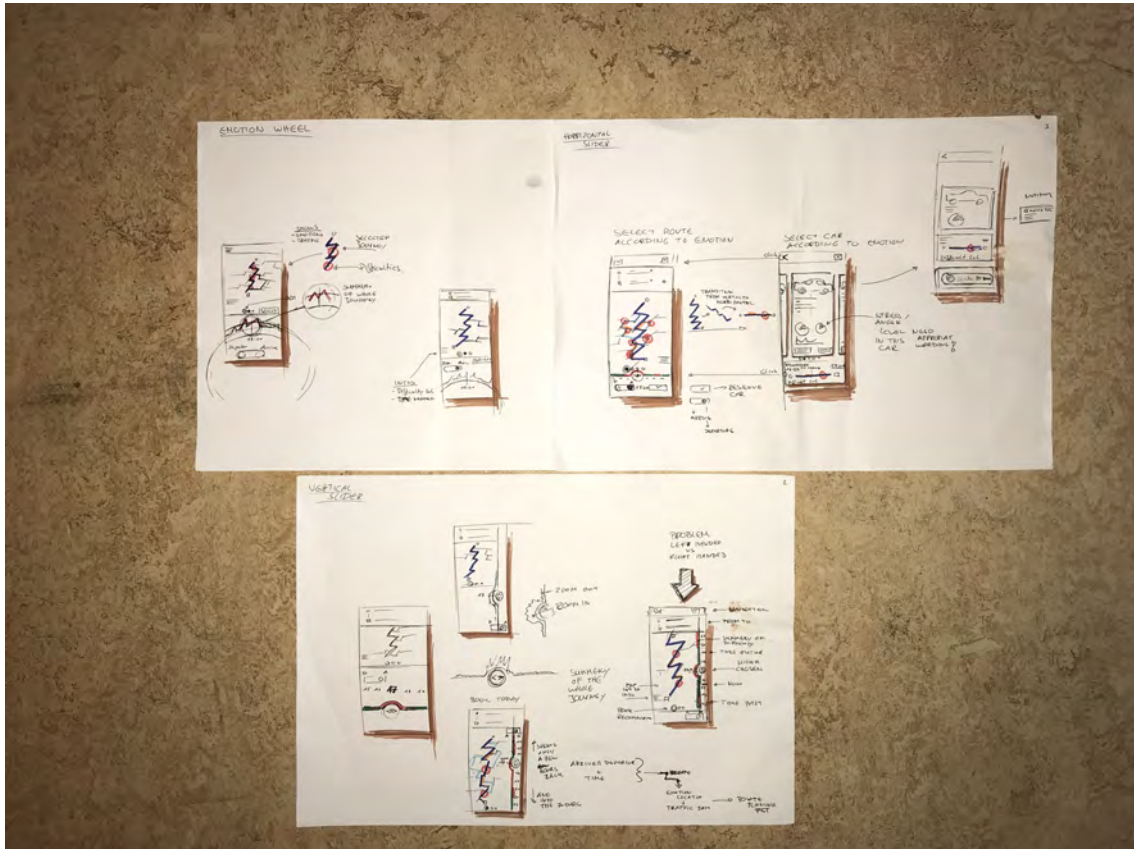


Figure 4.2: Wireframe sketches on paper

4.8 Prototyping

Method Description: Prototyping is a physical realization of a product, concept or idea into a tangible form. The tangible form can diversify into levels of fidelity. The level of fidelity can be distinct into low-fidelity and high-fidelity. Low-fidelity are quick crafts most of the time out of paper, and high-fidelity have a high level of detail in terms of functionality and design. Furthermore, a prototype is intended to be tested in order to create new insights about the product, concept or idea.[43, p.138-139]

4.9 Formative Usability Evaluation

Method Description: Formative Usability Evaluation supports identifying which part of the concept works and does not work and why. It is also frequently used in

a design process to support rapid iteration to improve the concept. The method is used to build up tasks to be completed by the users, to ask them to think aloud and monitor the user behavior, to find out when the user is struggling.[26] For this kind of testing Low-fi prototyping are commonly used. Low-fi prototyping is a variant of 4.8 Prototyping. A low-fi prototype is produced quickly and can be tested immediately to make rapid improvements. This makes it possible to work in a loop between improving the prototype and testing. The testing was done with 5 people each iteration at Volvo Car Design Studio in a Formative Usability Evaluation.

The first version of the idea was born with participants who were found in the instant environment of the author. The participants were people from Volvo car UX Design Studio. The testing was organized into a task for each function. The participants had to think out loud and the problems that occur during the testing were discussed instantly.

In order to test the concept, first paper prototypes (shown in figure:4.3) got created to test the concept of planning trips with a car. The test results which are necessary for the first iteration are stated in 5.6.1 Test results form the first concept version.

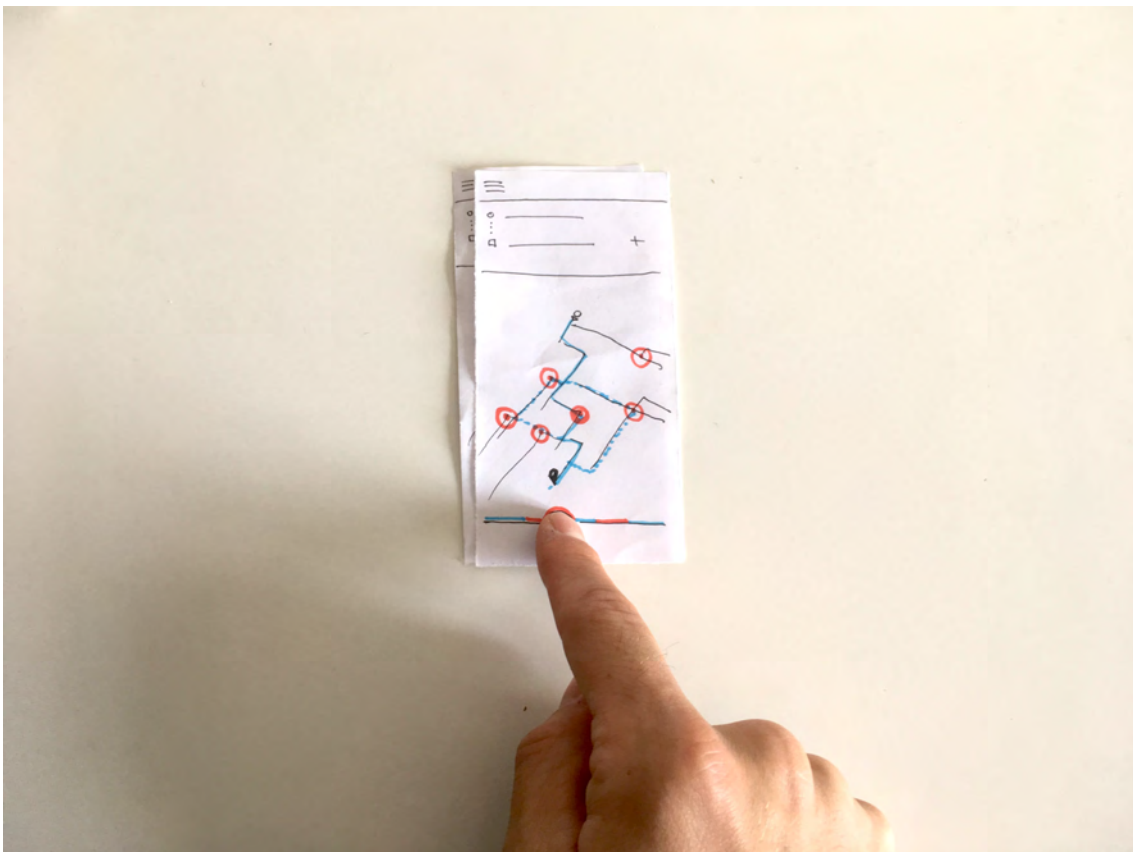


Figure 4.3: Low-fi prototyping with a paper prototype

After an iteration of the first concept a second version of the concept got created,

which still is an application for route planning on a smartphone but with a focus on shared cars. The concept is divided into four different features called Prevention, Education, Evasion, Motivation. **Prevention** is where the user is planning routes and booking cars with the help of a shared traffic heat map between users. This should prevent stress and anger in order to plan routes which avoiding locations which can cause stress and anger. In case there is no way around a certain location, the user gets informed when he is coming close to an area like this while driving. **Education** is where the user gets into a process of reflecting and educating on his own driving behavior and what can happen when he is driving stressed and angry. **Evasion** is a safety function that uses autonomous Level 2 features (3.8.2 Levels of Autonomous driving) like ADAS in a proactive manner to keep the driver and others safe from stressed and angry driving behavior. **Motivation** is a rewarding system that should motivate the user to use the system and create a positive experience with good traffic behavior.

The new concept got tested with digital wire-frames (see figure:4.4) and a interactive hi-fidelity prototype (see figure:4.5) with Sketch App[57] and Mirror App[56] on a smartphone and tablet. The test results which are necessary for the second iteration are stated in 5.6.2 Test results form the second concept version.

Regarding fewer test results to the second version (see figure: 4.6) of the concept the author decided after taking the last results into account for the third version of the concept to start creating a visual design.

4.10 Visual Design

***Method Description:** Visual design is intended to shape a concept into a visual form. Wire-frames that have already been created for navigation architecture will be enhanced with illustrations, photography, typography, space, layouts, and color, thus improving the concept's user experience and usability. Designers need to make visual design considerations on gestalt properties, space, hierarchy, balance, contrast, scale, dominance, and similarity in order to perform a visual design.[75] At the beginning a mood board can define the overall tone for visual design.*

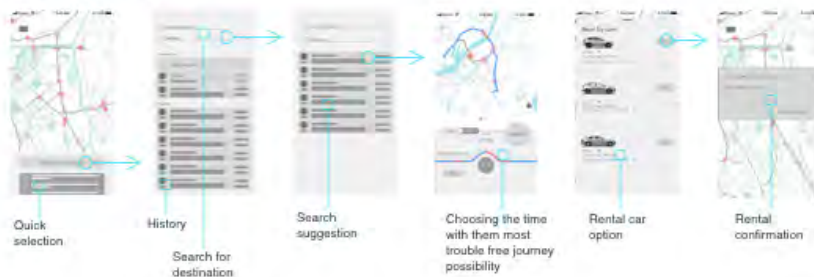
4.10.1 Moodboard

***Method Description:** Moodboards consist of collected images that are relevant to the topic. Images that set the mood for the UI or example elements from other already existing UI's. This helps to stay consistent through the design process and to define UI styles and themes.*

The Moodboard shown in figure:4.7 got used to find the right style (dark/light Theme, play-full/serious, etc.) for the Volvo Intuit application.

Volvo Intuit. — Wireframes V1

PREVENTING



EDUCATING



EVASION



MOTIVATING



Figure 4.4: Wire-Frames, first version of the Concept

4.10.2 Designing the Graphical User Interface

A step after wire-framing is the graphical user interface (GUI). If a wireframe has been tested and iteratively improved a few times already, a GUI will be created. In

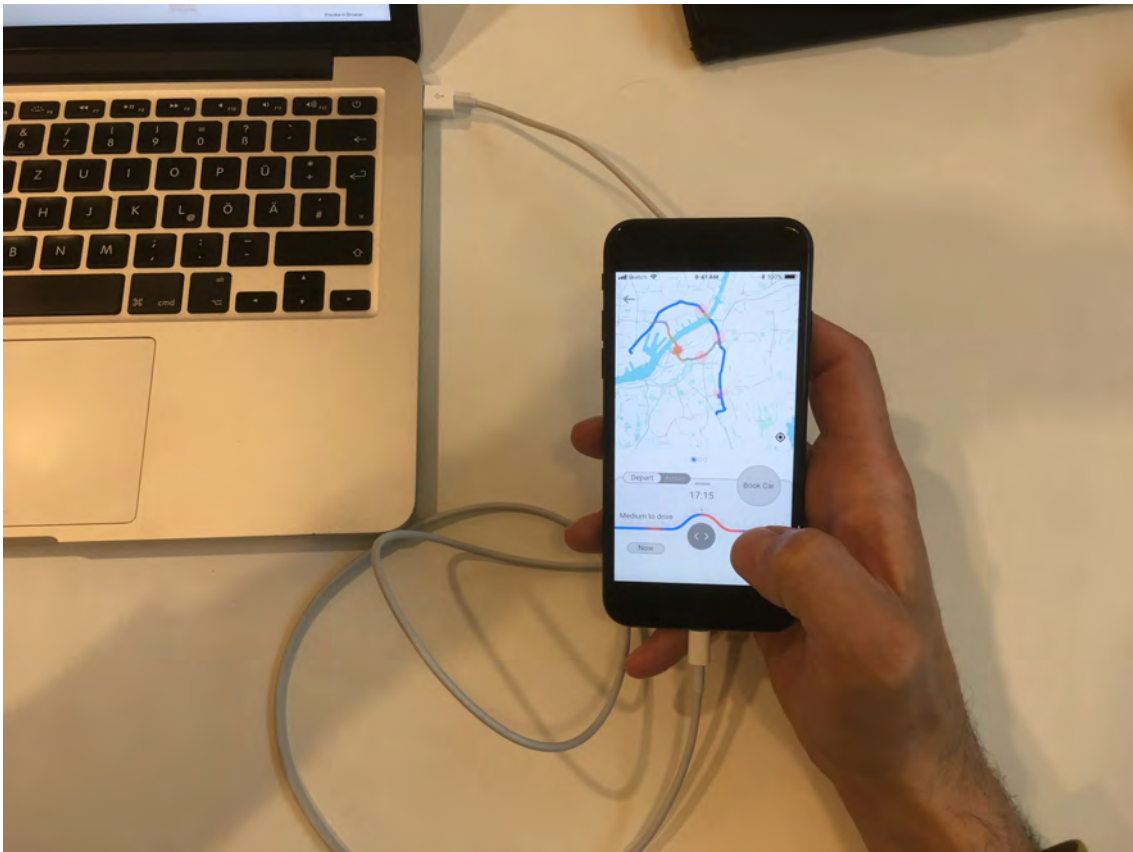


Figure 4.5: Hi-fi Prototype, first version of the Concept

a GUI, the wire-frames navigation concept is needed to select the right elements for navigation. In addition, the Moodboard (4.10.1 Moodboard) helps to create color patterns and styles of icons.

Designing a GUI is a trial and error with different styles to follow the 4.10.1 Moodboard. At the end a design system is created (shown in figure: 4.8) which helps to create a final user flow out of the wire-frames. This new flow is important for the prototype which will be used in 4.11 Summative Usability Evaluation.

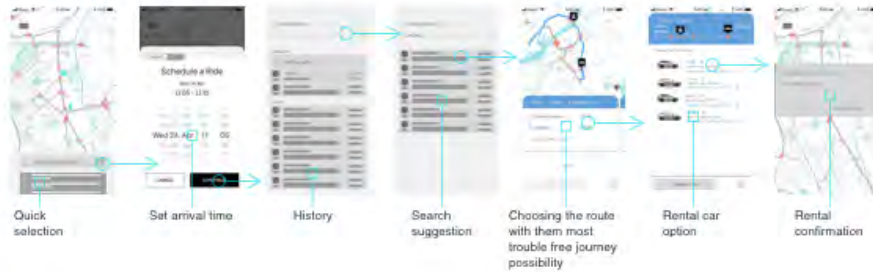
4.11 Summative Usability Evaluation

***Method Description:** Summative Usability Evaluation is an evaluation method that is performed when a design is completed. This method can be performed as a Formative Usability Evaluation that the user has to perform tasks by using the design. Unlike Formative evaluation, this method is unassisted to simulate real-life use.[26]*

A scenario was created and tested with 5 participants as recommended by Jakob Nielsen in "Why You Only Need to Test with 5 Users"[78] for the Summative Us-

Volvo Intuit. — Wireframes V2

PREVENTING



EDUCATING



AVOIDING



MOTIVATING



Figure 4.6: Wire-Frames, Second version of the Concept

ability Evaluation.

The scenario was to plan a trip to travel from the current position at Chalmers Johanneberg at the architecture library to Liseberg at a concert starting at 10:45.

The test persons were 3 male and 2 female testers between the ages of 25-31 years old. The testing tasks were divided into Prevention, Education, Evasion, Motivation (see figure: 4.9). Each task consists of sub-tasks. The test results which are necessary for a last iteration are stated in 5.7 Summative Usability Evaluation Results.

In conclusion, it is quite clear that the feature education has potential but in its current state, it needs a new way of how it educates people. Furthermore, Evasion failed completely. This is quite interesting because from the A.2 In-Depth Interview result it got discovered that people will accept taking power away when they see that they go saved for this reason. This could have several reasons, first, the design from the author was not good enough or because of 6.4.2 Limitation of Research.

4.12 Volvo Intuit, final design

The screen flow as shown in 4.10 represents the final design. This design took the results from 4.11 Summative Usability Evaluation into account in order to create the final design of Volvo Intuit.

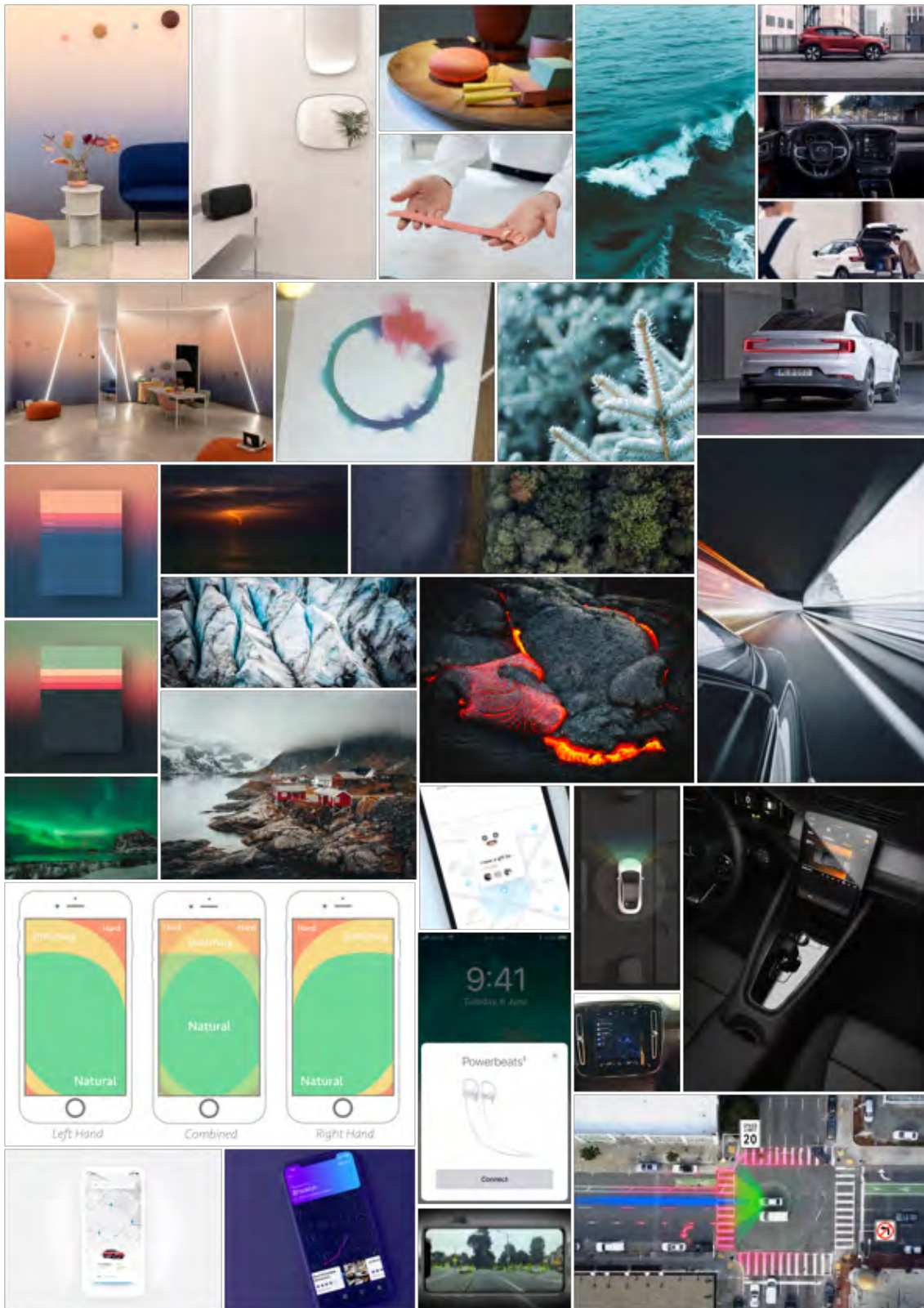


Figure 4.7: Mood board for Volvo Intuit Concept

4. Design Process

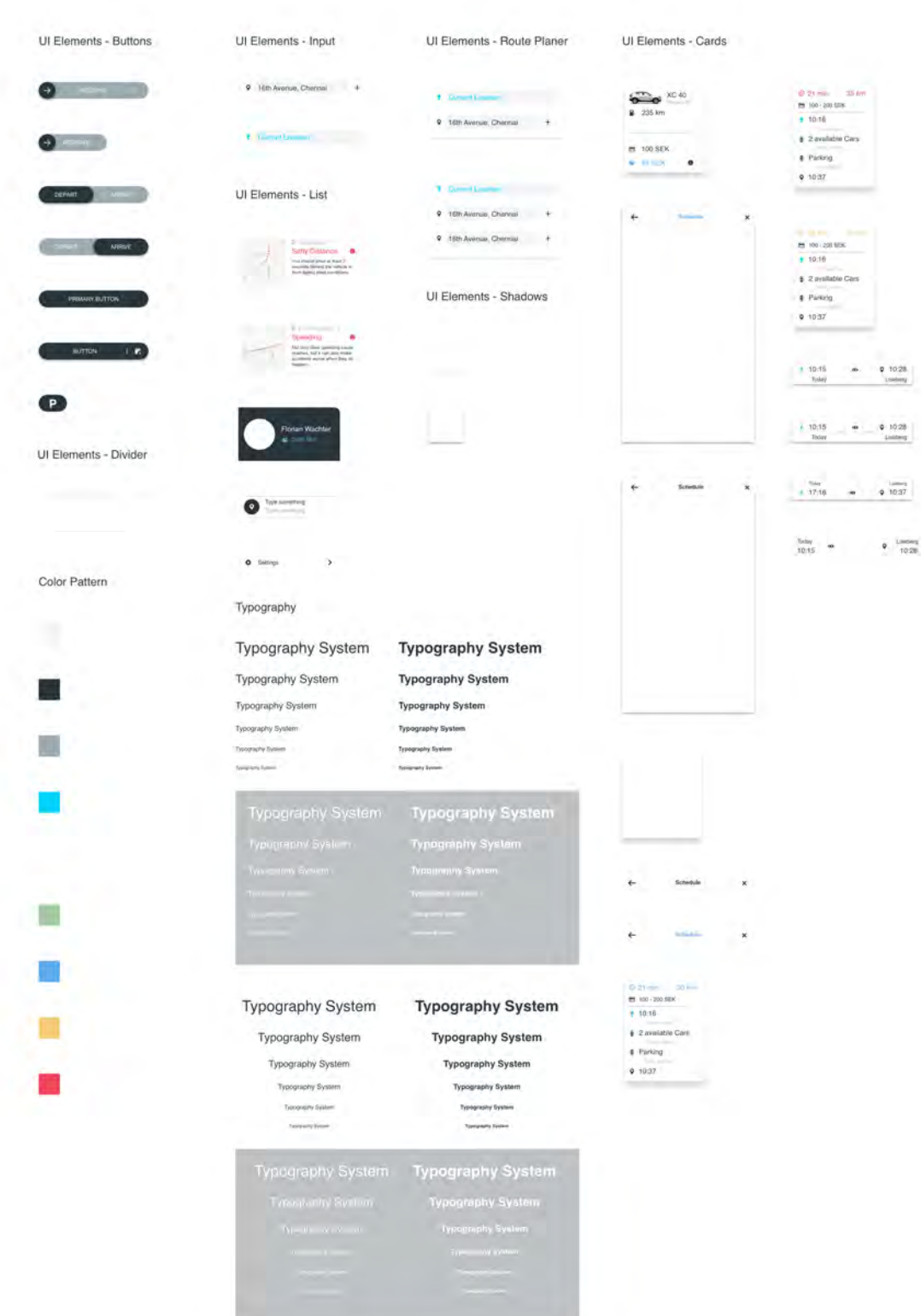


Figure 4.8: Design system for Volvo Intuit



Figure 4.9: Summative Usability Evaluation - Task list

4. Design Process

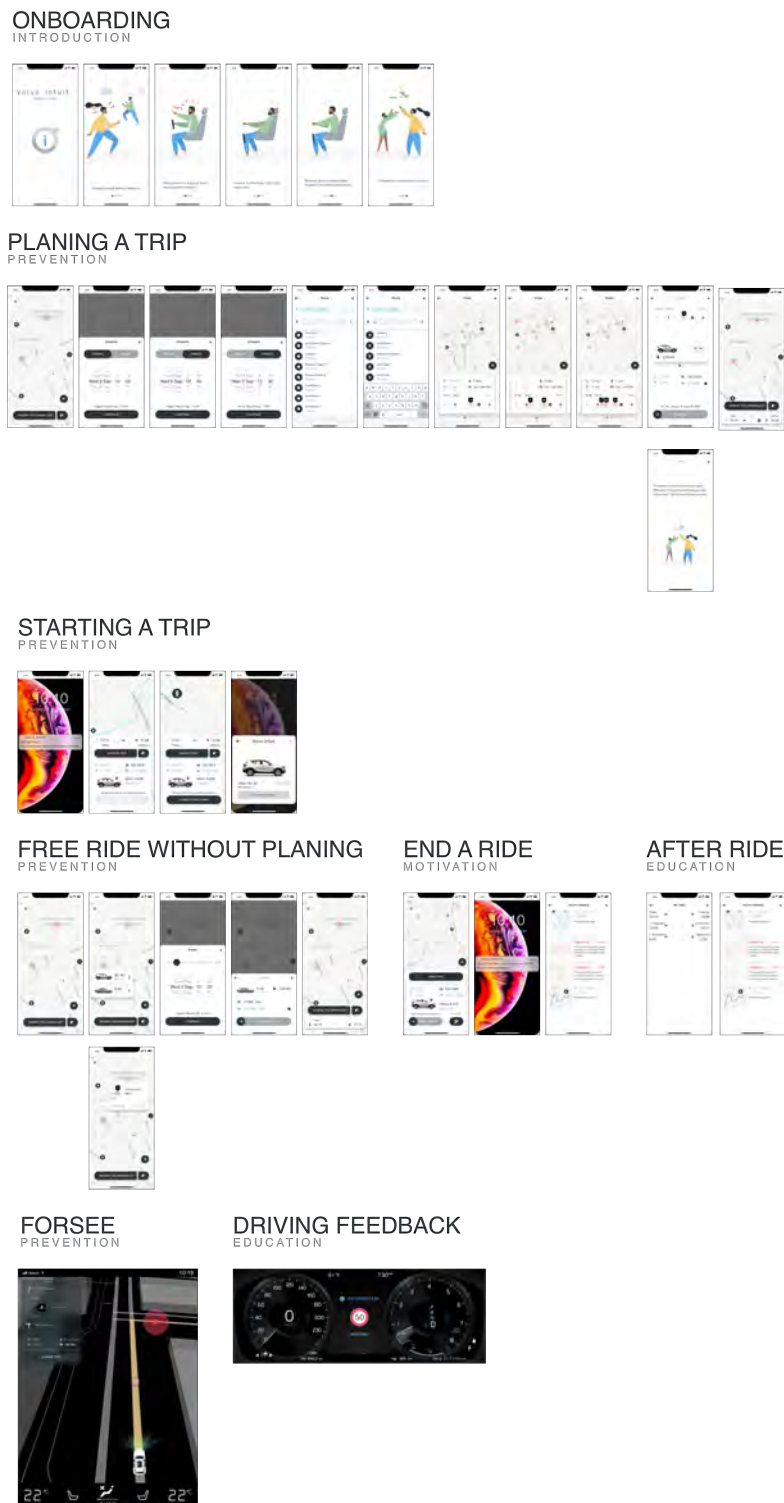


Figure 4.10: Volvo Intuit, the final design

5

Results

This chapter includes the research results based on safety-critical emotions and a design concept to minimize the risks of emotional driving.

5.1 Expert Interviews Result

The expert interview results consist of three transcribed interviews in the field of AI, emotions, and user needs in the automotive industry.

5.1.1 Specialist in Data Analysis at Volvo Cars

Expert interview with a specialist in Data analysis of Volvo cars. The Author expected from this interview to get more insights about autonomous driving, AI in cars, ML in cars.

What is The Difference Between AI, ML, and NN?

There is a clear distinction between AI and Machine learning. ML is about prediction and automation of tasks. AI is about Planning and reasoning, in an open environment. In order to do AI, you must be able to do prediction. This means AI is living on ML and NN. For instance, an AI is predicting different future outcomes on a current situation, then it will choose the closest suitable outcome according to my goals. So, AI is planning for a long term outcome. Machine learning and AI is inspired by the human brain. We learn to act and react which is comparable to ML for example how to steer my muscles compared to eye coordination. This is not a concept this is a reality, today.

when it comes to AI. The AI, due is more about planning what I want to do with my muscles. If I am thirsty, I will plan to walk to the kitchen, because there is water on the table. That's planning and not steering because I have to plan where I will find water. Moreover, with machine learning, you can only do what is in the data, the input kind of defines the outcomes. For instance, If you see a mouse running behind the curtain. The ML will not see the mouse and will say there is no mouse, but the AI will reason that the mouse ran behind the curtain and will say, I think the mouse is behind the curtain.

How do AI works?

The brain of the AI is building models of "how does the world works". According to

this "world works" model the AI can reason and create new models which describe possible outcomes. Furthermore, the AI is doing the planning and desired outcome.

What is the motivation for ML and AI in the car?

ML can automate functions in cars. For instance, climate control. ML helps to personalize, the climate control by the system collecting statistics about the drivers and its environment. Another Example is Autonomous driving, the ML is automating the behavior of the vehicle like speed, braking, and steering. In contrast, AI is used in cars to do planning. For instance, If the car should drive from one location to another, it has to turn in a different direction in order to follow different plant roads. Turns need to be planted in advance according to local state and future outcome.

Another aspect of AI in cars is Object collision avoidance, If an ML recognizes a Ball on the side of the road, it will maybe classification it as a ball or maybe it can not see the ball. The AI, due can classification it as a ball and also reason that with this ball maybe playing children can occur on the side of the road. As a result, the AI will slow down the car in order to be prepared if a child evidently jumped into the road.

What is the reality today?

ML, NN, and Narrow AI are the reality today but there are only as good as the amount of data. AI makes it possible with a limited amount of data to predict the same outcome as an ML with a lot of data. In order to become really good, an AI needs a model about How the world works. In order to get these data, we are sending a lot of cars on the road, which are collecting data for us, out of these data we creating models which we using for reasoning, planning, and predicting.

What hardware is needed for ML and AI?

Really powerful CPUs or GPU's. Google developed a processor called TPU, which is powerful and power efficient because GPU's and CPU's are really power hungry when it comes to ML and AI.

What is DL?

DL is an enhancement of ML and it is really efficient. But it has one drawback, if a model got trained with DL, it can work successfully but if I look at the system in a raw format, a Human cannot understand how it learned, its a black-box. I can not guess what the system will do in an unpredicted situation.

Hoew does the future looks like with AI?

The future will be a different place, The AI will be everywhere and it will not be visible for us.

5.1.2 Psychologist with focus on behavioural therapy

The author expected from the interview with a Psychologist, to get a better understanding of Basic Emotions (3.1.1 Basic Emotions) and how to deal with them in a

traffic situation.

How do emotions get generated?

Emotions are existing out of 7 base emotions. Emotions are body functions in order to protect us. For instance, If a wild animal is attacking us we get fear and run away, it would be bad for us if we would stay. If the body is generating fear all the blood goes away from the extremities and into the important organs that you can react quickly. This helps to make a decision without rationality. This makes emotions to vital functions of the human body.

How to stop or change Emotions?

To stop emotions is not possible, but it is possible to regulate emotion. For instance with "Emotions Regulations Techniques". Emotions consist of "primary-" and "secondary-emotions". Sometimes, emotions are not really beneficial to me, but the need behind the emotion makes sense. For instance, being angry makes the person seeking justice or dispute for its situation. Actually, an emotion serves to tell you what you actually need right now, the question is more about how you implement that?

What are Emotions Regulations Techniques?

This can be "Breathing Techniques", which can help to measure the level of the emotion but also actively to control the emotion. Further, it can be "Cognitive Strategies", which means a cognitive reassessment of the situation. In order to find out what thought makes me angry, I can reprocess this thought in order to make the thoughtless bad for me. Relaxation Exercises and PMR can also help to regulate. Additionally, it is proven that before every emotion accrues a thought is appearing in the mind of the person who is experiencing the emotion.

How does Anger become, aggression?

Base emotions have gradations, anger is lower in intensity as aggression because aggression is higher in intensity.

What makes aggression so dangerous?

In relation to driving aggression has nothing positive to contribute to driving, but basically, are these emotions important for the human body. People who got aggressive tending to a "hyper-focus" and then they only focus on what makes them angry.

What an Emotional Dimension?

First, a demotion is measured in "Arousal", which is a quantitative dimension and characterize the intensity of the emotion. Second, the "Valence", which is a hedonistic value and describes the emotional nature into positive and negative.

How to test Emotions?

There are some techniques, for instance: Ask the person which kind of emotion the person experiencing, a graphic with example emotions can support this possess. Furthermore, face recognition can be used in a lavatory environment and there are

working quite well, but there are quite expensive. The last method can be "Body tracking", people walk differently if there are infected in different states of emotions.

5.1.3 Costumer Researcher at Volvo Cars

With questionnaires and interviews, Volvo cars keeps track of its customers continuously. Volvo classifies this data as extremely delicate. The author anticipated to gain some insight into Volvo's actual user of Volvo cars through this interview. The interview's raw data cannot be published for reasons of secrecy, but Volvo cars has agreed to 9 user needs (stated in 4.2.2 The User Needs) that have been discovered. These user needs are of great value to the project because the user needs help to create a deeper user understanding. This leads to better concepts and solutions to the fundamental issues the user group is suffering from.

5.2 The User Needs in Volvo cars

The user needs got created through a Expert Interview (as stated in 5.1.3 Costumer Researcher at Volvo Cars). The following table provides 9 user needs researched for a better comprehension of the real user.

1. The user needs a seamless and trouble-free journey to his destination.
2. A user needs safe and convenient interactions.
3. A user needs transparency.
4. A user needs an experience that is getting better every day.
5. A user needs to perform effectively.
6. A user needs personalization.
7. A user needs intelligence that minimizes the user's cognitive workload.
8. A user needs minimal interaction.
9. A user needs support to minimize driving errors.

5.3 Safety critical emotions

To answer the first research question "**Which emotions cause significant harm to the driver and other road users when driving?**" (stated in 1.2 Research Questions) the author investigated from research (3.10 Literature Review) two safety-critical emotions: anger (3.10.1 Anger, stimulus and behavior) and sadness (3.10.2 Sadness, Stimulus and Behavior).

There are evidences that happiness degenerates driving as much as anger. Reason for that is high arousal, energy and excitement increases the illusion of control. Drivers get easier distracted which can cause dangerous traffic situations.[36]. But happiness needs more research in order to become relevant that the reason why happiness just gets mentioned and not becomes relevant for further development in this project.

5.3.1 Investigations regarding Safety critical emotions from the Questionnaire

The following table consists out of findings which got investigated from the Questionnaire (4.1.2 Questionnaire) regarding safety-critical emotions. These findings help to prove findings from the literature review (3.10 Literature Review) and in addition to complete insights regarding safety-critical emotions.

Findings — Questionnaire

- People do not know how emotions can impact driving compared for example to driving drunk or under the influence of drugs, people got educated that the influence makes the driving less safe.
- People do not know how to deal with emotions while driving, because it happens often without a clear awareness about that emotional driving takes a risk on safe driving.
- People do not know the specific errors which arise with emotional driving to keep track on it in order to correct and avoid these errors.

5.3.2 Investigations regarding Safety critical emotions from the Expert Interview with an Psychologist

The following table consists out of findings which got investigated from the Expert Interview with a psychologist (5.1.2 Psychologist with focus on behavioural therapy) regarding safety-critical emotions. These findings help to prove findings from the literature review and Questionnaire (3.10 Literature Review) and in addition to complete insights regarding safety-critical emotions.

Findings — Expert Interview Psychologist

- Emotions protect us, which means quick response without rational decisions
- Emotions are from past protection mechanisms, emotional reactions are not appropriate in automobiles.
- Cognitive strategies can regulate emotions
- Breathing techniques can regulate emotions
- Relaxation and progressive muscle relaxation can be used to regulate emotions
- Aggressive individuals tending to be "hyper-focused," focus only on the problem, turning more and more negative.

5.3.3 The stress and anger in traffic model

The Anger in traffic model shows how anger and stress can occur in traffic based on the ABC-Model (3.1.5ABC-Model by Albert Ellis) by Albert Ellis. The model as shown in the figure: 5.1 can be a tool to check whether or not a driver-based situation can cause stress or anger. This helps to indicate rules (as stated in 5.8 Volvo Intuit) that are essential for the AI to comprehend if a situation can be categorised as difficult to drive area for the driver.



Figure 5.1: The Anger in traffic model based on ABC-Model from Albert Ellis (3.1.5ABC-Model by Albert Ellis)

5.4 Point of View about Angry Driving

- A user need to leave and enter the car early enough because unexpected happenings and time pressure occurs stress in traffic for the user.
- A user needs to avoid stress while driving because stress and driving can easily result in anger.
- A user need some kind of assistance because anger in traffic makes driving errors.
- A user need some kind of assistance because users have troubles to think rationally while being stressed and angry.
- A user need some kind of assistance because users tending to accelerate and speeding while being angry.
- A user need some kind of assistance because users tending to do risky maneuvers (includes lane deviation).
- A user need some kind of assistance because users tending to drive closer to the car in front.
- A user needs data transiency because its important for the user to know where data got stored.
- A user needs data transiency because the user wants to know what the system is doing with created and stored data.
- A user needs control over the system because a user wants to feel in control.
- A user needs information about risks which can happen while driving angry because users want to realize something is necessary in order to save their life's.
- A user need reflection on own driving behavior because people who reflecting on there own driving behavior creating awareness of own errors while driving.
- A user need to avoid anger while driving because angry drivers make other drivers angry and so on.

5.5 Minimizing the risk of emotional driving

In order to minimize the risk of emotional driving, especially the risk of angry driving, the author created a Design Concept 5.8 Volvo Intuit. This Design Concept got created by Design Requirements (5.5.1 Design Requirements) which got created based on knowledge from safety-critical emotions (5.3 Safety critical emotions). The knowledge of safety-critical emotions was an investigated through results (5.3.1 Investigations regarding Safety critical emotions from the Questionnaire) of a Questionnaire (4.1.2 Questionnaire), results (5.3.2 Investigations regarding Safety critical emotions from the Expert Interview with an Psychologist) of a Expert interviews (4.1.1 Expert Interviews), and a In-depth Interview (4.3 In-Depth Interview).

5.5.1 Design Requirements

The Design Requirements were created from knowledge of safety-critical emotions which got investigated through results (5.3.1 Investigations regarding Safety critical emotions from the Questionnaire) of the Questionnaire (4.1.2 Questionnaire), results (5.3.2 Investigations regarding Safety critical emotions from the Expert Interview with an Psychologist) of the Expert interviews (4.1.1 Expert Interviews), and the In-depth Interview (4.3 In-Depth Interview). The Requirements are divided into Non-functional Requirements and Functional Requirements. Non-functional Requirements specifies how the system shall perform a certain function and functional Requirements specifies what the system should do.

Non-functional Requirements

1. The system shall provide a mobile user interface (Mobile UI).
 - (a) The Mobile UI shall provide onboarding for first-time use.
 - i. The on-boarding shall provide in-formations why this app exist, and whats the benefit out of it.
 - ii. The on-boarding shall help to connect to the car share provider.
 - iii. The on-boarding shall help to set payment settings.
 - (b) The Mobile UI shall provide easy navigation.
 - i. The navigation shall provide navigation on one level.
 - (c) The Mobile UI shall provide a map.
 - i. The map shall provide visualized difficult locations to explore.
 - ii. The map shall provide own position.
 - iii. The map shall provide a center map interaction.
 - iv. The map shall provide visualized places where cars are located.
 - (d) The Mobile UI shall provide for a menu.
 - i. The menu shall provide for payment settings.
 - ii. The menu shall show the trips of the user with information about the trip.
 - iii. The menu shall provide a way to add more smart devices (smart-watch).
 - iv. The menu shall provide for general settings.
 - v. The menu shall show the version of the app.

- vi. The menu shall show your savings.
 - vii. The menu shall show your profile.
 - (e) The Mobile UI shall provide interaction to create a trip
 - (f) The Mobile UI shall provide a "Destination Search Interaction".
 - i. The "Destination Search Interaction" shall provide for input, such as time, date and destination.
 - ii. The "Destination Search Interaction" shall provide for history (old destinations).
 - iii. The "Destination Search Interaction" shall provide for auto-completion.
 - iv. The "Destination Search Interaction" shall provide for a trip with depart or arrival date, time.
 - v. The "Destination Search Interaction" shall take the current location as a starting point with the option to change.
 - (g) The Mobile UI shall provide a "select a trip interaction".
 - i. The "select a trip interaction" shall provide recommended routes structured from easy to difficult.
 - ii. The "select a trip interaction" shall provide arrival time, duration time, distance, walking time, driving time, costs.
 - iii. The "select a trip interaction" shall provide a map with different routes.
 - iv. The "select a trip interaction" shall provide why easy or difficult to manage.
 - v. The "select a trip interaction" shall provide a selection of available cars.
 - vi. The "select a trip interaction" shall provide to renovate the car for the trip.
 - (h) The Mobile UI shall provide an approach to a reserved car interaction.
 - i. The "Approach a Reserved Car Interaction" shall provide an easy way to connect with the car.
 - ii. The "Approach a Reserved Car Interaction" shall provide an easy way to open the car.
 - iii. The "Approach a Reserved Car Interaction" shall provide an easy way to find the car.
 - iv. The "Approach a Reserved Car Interaction" shall provide information about the car, such as car number plates, car model, car image, cost, possible savings.
 - v. The "Approach a Reserved Car Interaction" shall provide to change the destination of the trip.
 - (i) The Mobile UI shall provide an approach to a reserved car interaction.
2. The system shall provide a user interface inside the car (Car UI).
 3. The Car UI shall provide a driver educational information system.
 - (a) The "driver educational information system shall provide information about the risks of stress and driving.
 - (b) The driver educational information system shall be able to create an awareness of driving with stress.

-
- (c) The driver educational information system shall provide information about the risks of angry and driving.
 - (d) The driver educational information system shall be able to create an awareness of driving with anger.
 - (e) The driver educational information system shall provide education for misbehavior in traffic.
 - (f) The driver educational information system shall provide a visualization to make locations with high anger and stress visible.
 - (g) The driver educational information system shall provide to inform without taking the attention away from the road for too long.
 - (h) The driver educational information system shall inform the user about the actions the system is doing.
4. The Car UI and the mobile UI shall be capable to motivate the user.
- (a) The motivation shall make the driver willing to behave in traffic.
 - (b) The motivation shall make the driver to use the system again.
 - (c) The motivation shall make the driver focus on good behavior in traffic.
 - (d) The motivation shall make the driver focus on avoiding to get stressed and angry.
 - (e) The motivation shall show focus on positive re-enforcement (how good the user is doing rather than showing how bad the user is doing).
5. The Car UI shall provide a navigation system to the set destination.
- (a) The navigation system shall provide directions to drive.
 - (b) The navigation system shall provide information about what will happen on the trip.
 - (c) The navigation system shall provide a changing destination.
 - (d) The navigation system shall provide information about left time until destination.
 - (e) The navigation system shall provide information about left distance.
 - (f) The navigation system shall provide information about savings and cost.
 - (g) The navigation system shall provide a 3d map with marks on upcoming difficult spots on the road.
 - (h) The navigation system shall provide descriptions about the difficult spots.
6. The Car UI shall provide notifications.
- (a) The notifications shall provide information about miss-behavior from the driver.
 - (b) The notifications shall provide icons and text.
 - (c) The notifications shall provide fast interaction.
 - (d) The notifications shall provide information which support assistance got activated.
7. The Car UI shall provide navigation on one level.

Functional Requirements

1. The system shall record locations with high anger and stress occurs.
2. The system shall be capable to share anonymously recorded locations with high anger and stress with other system users.
3. The system shall be capable to make reasoning

- (a) The reasoning shall classify the driver's emotion into normal, stressed and angry.
 - (b) The reasoning shall make use of the driver's hearing rate data.
 - (c) The reasoning shall make use of the driver's blood pressure data.
 - (d) The reasoning shall make use of the driver's posture.
 - (e) The reasoning shall make use of the driver's facial expressions.
 - (f) The reasoning shall make use of the driver's driver location (GPS / Road).
 - (g) The reasoning shall make use of driver's traffic situation, such as traffic jam, construction work, city traffic, traffic lights, route constellation.
 - (h) The reasoning shall be capable to identify good and bad driving behavior.
4. The system shall be capable to make planing
 - (a) The planning shall be capable to use shared data and personal recorded data.
 - (b) The planning shall be avoided locations with high anger and stress.
 - (c) The system shall provide a seamless journey
 5. The system shall react with driving assistance (pro-active), in case of traffic miss-behavior or stress and anger.
 6. The system shall be able to communicate within different devices (mobile to a car).

5.6 Formative Usability Evaluation Results

The following subsections contain lists of test results from the Formative Usability Evaluation (4.9 Formative Usability Evaluation). These results are necessary for the iterative process of a Design Thinking (3.7.1 Design Thinking).

5.6.1 Test results form the first concept version

The following table is listing the testing results from the first Formative Usability Evaluation (4.9 Formative Usability Evaluation) of the concept including the features **Preventing**, **Education**, and **Motivation** described in 4.6.4 Minimum Viable Concept.

Test Results, first version of the concept:

- Car drivers do not like to plan there trips over there calendar because this means with every entry an extra amount of planning.
- Car drivers like a dark mode but feel it is inappropriate with an app which deals with emotions.
- Car drivers do not like to see in a statistic how bad they drive because it feels like paternalism from an application.
- Car drivers think to add a car to the app is time-consuming, because most of the drivers using car sharing, which means there are not using the same car every time.

- Car drivers think connecting a phone to car makes problems because of pre-views experience with connecting the phone to a car over Bluetooth to listen to music or having phone calls in the car.
- Car drivers think the system takes to long in order to become valid if it only uses own created data.

5.6.2 Test results form the second concept version

The following table is listing the testing results from the second Formative Usability Evaluation (4.9 Formative Usability Evaluation) of the concept including the features **Preventing**, **Education**, and **Motivation** described in 4.6.4 Minimum Viable Concept.

Test Results, second version of the concept:

- Car drivers have problems to decide on the best time to take for a ride because the driver just wants to know when it is best to drive.
- Car drivers cannot relate to experience measured into a point system.
- The connection between discount and experience is not clear enough.

5.7 Summative Usability Evaluation Results

The following subsection contains a lists of the test results from the Summative Usability Evaluation (4.9 Formative Usability Evaluation). These results are necessary for the iterative process of a Design Thinking (3.7.1 Design Thinking). The test results focuses on the concept features **Preventing**, **Education**, **Evasion**, and **Motivation** described in 4.6.4 Minimum Viable Concept.

The result of the Summative Usability Evaluation is the following: Prevention

1. **Planing the Trip** - Does the user understand how to set up a trip that he arrives at 10:30?
 - (a) Yes, but the user wants to book a car without setting a destination because he is living in the area and know the area quite good.
 - (b) yes, but the search for a location and set time button is not clear because the division on the button is visually not clear enough.
 - (c)
2. **Choose Route** - Does the user understand the concept of the most comfortable route?
 - (a) yes, but the user wants to get alternatives to driving if the destination is close because this makes the user feel that the app cares and not has the motivation to make a lot of money.
 - (b) yes, but the route on the map is not prominent enough because the lines are to thin.
 - (c) yes, but the red dots which indicates a difficult to drive area got not understand straight away because the symbol is not self explainable and got nowhere else explained.

3. **Choose Car & Reserve** - Does the user understand how to choose a car?
 - (a) yes, but the user wants to know which car has enough fuel or battery to make the trip because this and the cost of the car decides on if they take it or not.
 - (b) yes, but the savings got perceived as savings but everyone wanted to know exactly what is because everyone likes to save money.
4. **Approaching Car** - Does the user understand how to interact with the booked vehicle?
 - (a) yes, but the user is not sure if he has to be at the car in 5 minutes or start walking because the text just mentioned getting ready.
 - (b) yes, but the user wants to set the reminder to 10 minutes instead to 5 because to get ready is individual and not just 5 minutes.
5. **Navigation and Prepare** - Does the user foresee what is going to happen?
 - (a) yes, but the user has a problem to read the direction of the navigation symbols because he wants to read it from bottom to top.
 - (b) yes, but the user does not like the position of the "change route"- Button because it divides the savings and the distance to drive which are belonging together.

Education

1. **Misbehavior** - Does the user reflect and learn about his misbehavior?
 - (a) No, the user wants to know more details about the misbehavior notified by the notification because with more information the user can better reflect or relate to it.
 - (b) No, the user gets irritated by the Notification because the visualization feels like treating him badly.
 - (c) No, the user feels in a negative way judged, under pressed and stressed by the Notification because the notification looks intrusive and not helpful.
2. **Debrief** - Does the user want to improve by reflecting on and learning about their own behavior?
 - (a) yes, but the user wants to know more details, for instance how much he lost in savings with the misbehavior and how long the user misbehaved.

Motivation

1. **Reward the driver** - Does the user feel motivated to save money with good traffic behavior?
 - (a) yes, but the user would like to get more information or navigation where to find the information about its misbehavior.

Evasion

1. **Support for Misbehavior** - Does the user feel secure and supported?
 - (a) No, the user has the feeling to lose control because of taking the control away from the user.
 - (b) No, the user gets angry or irritated because losing control makes him feel mistreated
 - (c) No, the user feels unsafe with this function because losing control in traffic feels unsafe even if it is safe.

5.8 Volvo Intuit

This section describes the Volvo intuit design concept in its final state. Volvo intuit is about avoiding stress and anger in traffic. Anger and stress affect our judgment and fine motor skills which can lead to dangerous traffic situations.

To avoid means, **prevention** of stress and anger with trouble free driving. For this reason, the Volvo intuit application uses AI to reason driving areas that are high in the potential of stress and anger and with planing it plans the most convenient route around these areas.

This is possible with inside the car collected data about the driver by an IR camera (see figure: 5.2) that collects data from Bio-metrics (3.2.2 Biometrics) and body language (3.2.1 Body language). These cameras will be mandatory by the new EU law regulations of car safety in 2021 (3.8.1 EU law for car safety 2022). This makes this concept feasible by every produced car in 2021.

These two data sets together help the AI to recognize if a person is stressed or angry (3.2 How to track an emotion?).



Figure 5.2: Face recognition technology [66]

In addition, the car and its external cameras collect data through object detection, which enables context to be understood in order to classify certain objects in the surroundings as shown in figure: 5.3).

In order to make a statement about the current driver traffic situation, a process called sensor fusion (3.4 Sensor Fusion) is necessary where data from outside and inside the car gets fused together, to generate a data set which is comparable to

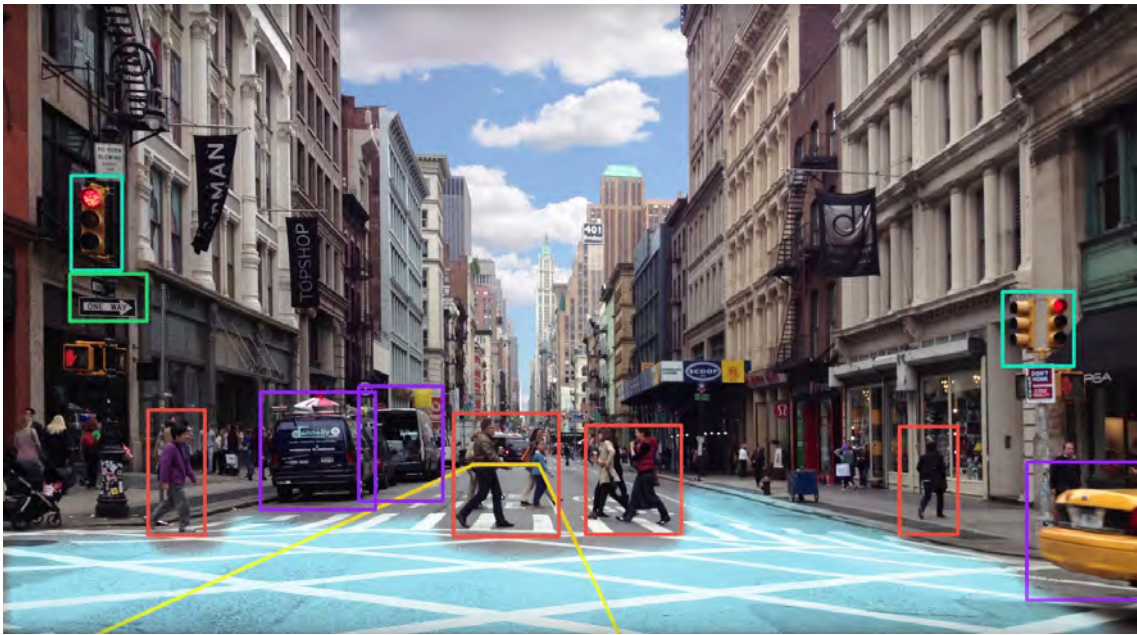


Figure 5.3: Object detection and classification to understand the surroundings and context[31]

other data-sets. This allows an AI to classify a situation (3.5.2 Ubiquitous computing) based on situations already learned.

For example, a person is driving a car. The car sensors track data outside as shown in the figure: 5.4 and tracking data inside as shown in the figure: 5.5. The AI can reason that if the user stuck in traffic, the person is likely to get stressed.

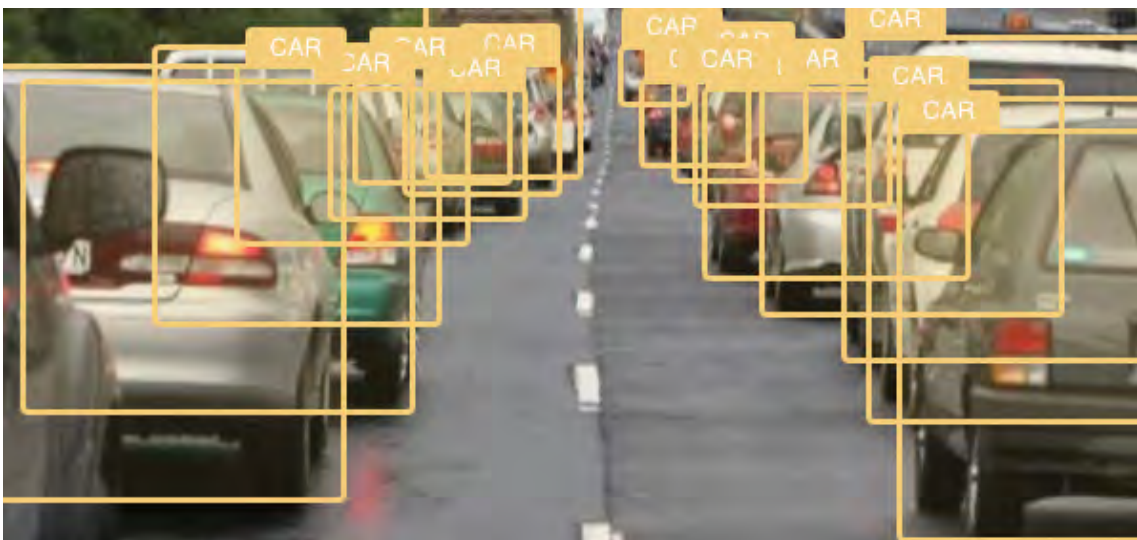


Figure 5.4: Object detection of a traffic jam

But this is not enough to make classified situations usable to mark a location as a difficult area to drive. The data set gets gathered together with time, location, to

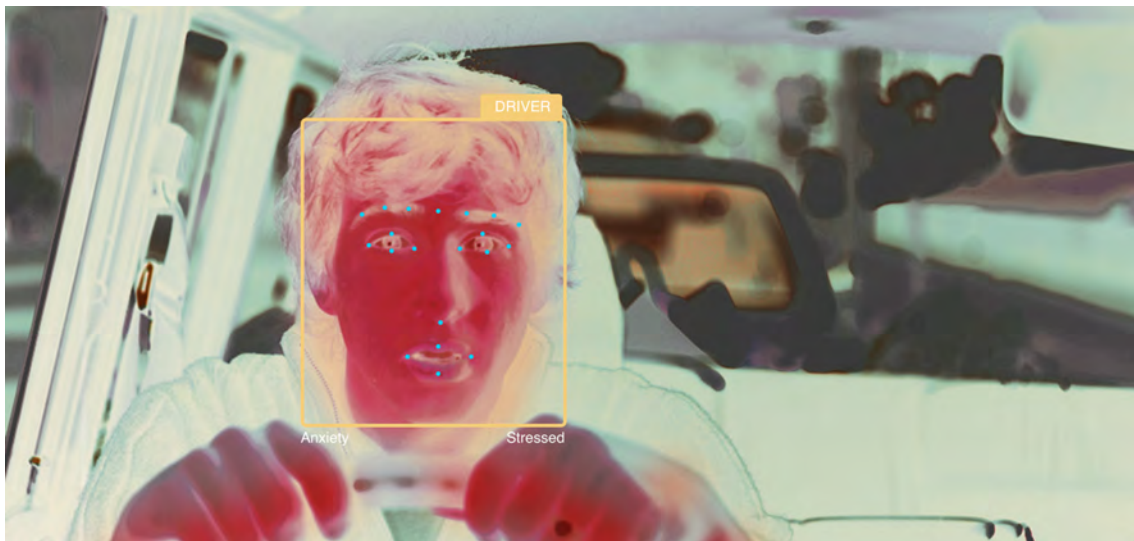


Figure 5.5: Face tracking of a driver

create an understanding of the situation. And in a second step, it will be compared to other users in this area to check if the classification of the situation is unique or a common thing. If its a common thing, it will be marked on the map (as shown in figure: 5.6).

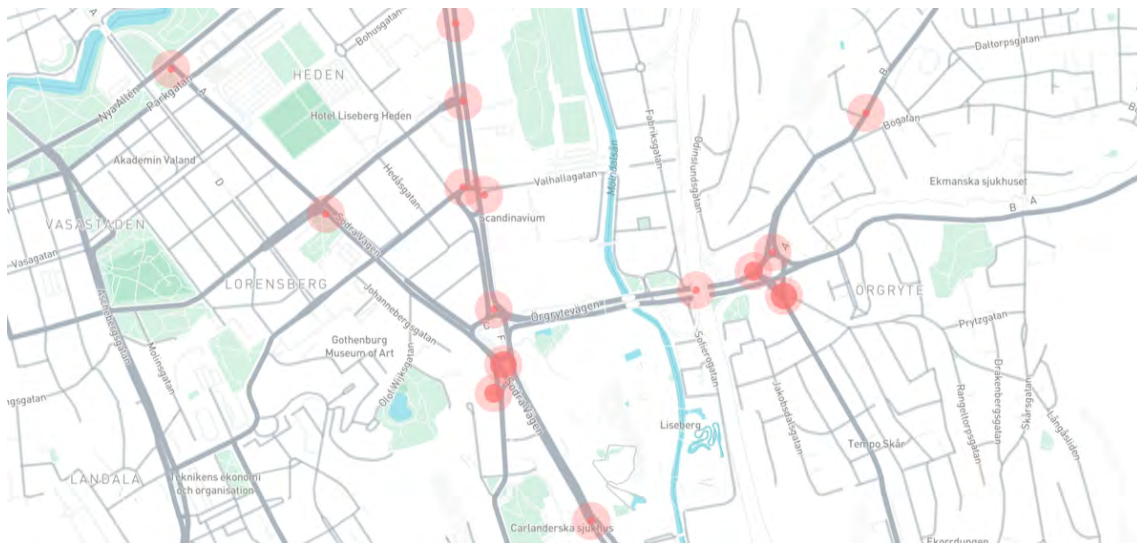


Figure 5.6: Stress and Anger Heat Map of Gothenburg, Sweden

Traffic is a dynamic process that changes depending on time and weekdays. For example, on a Friday afternoon, a street can be very busy and difficult but completely empty on a Saturday and not difficult at all.

In case an area that is difficult to drive shows less than no signs for being difficult. After some time, the mark will disappear. With this procedure, the map will remain updated. For example, this makes sense if construction works made an area difficult

to drive. After the construction work is finished and the area is no longer difficult to drive, as stated before, the mark will disappear.

This is helpful because normally locals in a city know how to navigate trouble-free based on long-term experience. You have to drive a lot to gain this knowledge of navigating in an area or a city. With Volvo Intuit, this knowledge is created and shared in a cloud (shown in figure: 5.7) by Volvo Intuit users, and every user gets a trouble-free drive experience, which contributes to the drivers well-being.

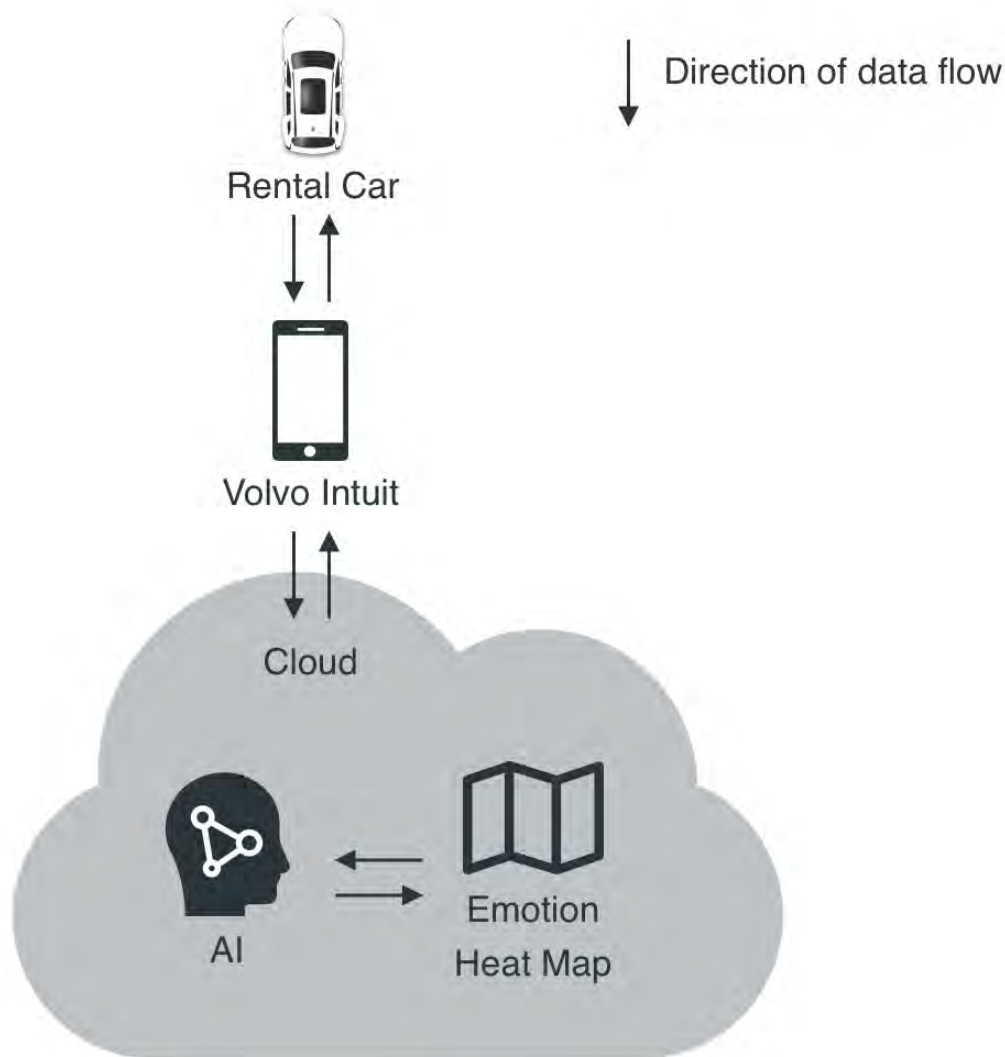


Figure 5.7: Volvo Intuit backbone system

In order to achieve such a trouble-free driving experience, the data from the heat map as shown in figure: 5.6 gets used to plan a set of options to drive, as shown in figure: 5.8. It plans a set of options because the user should still have the freedom

of choice. The options are color coded from the best route in green, to the worst route in red.

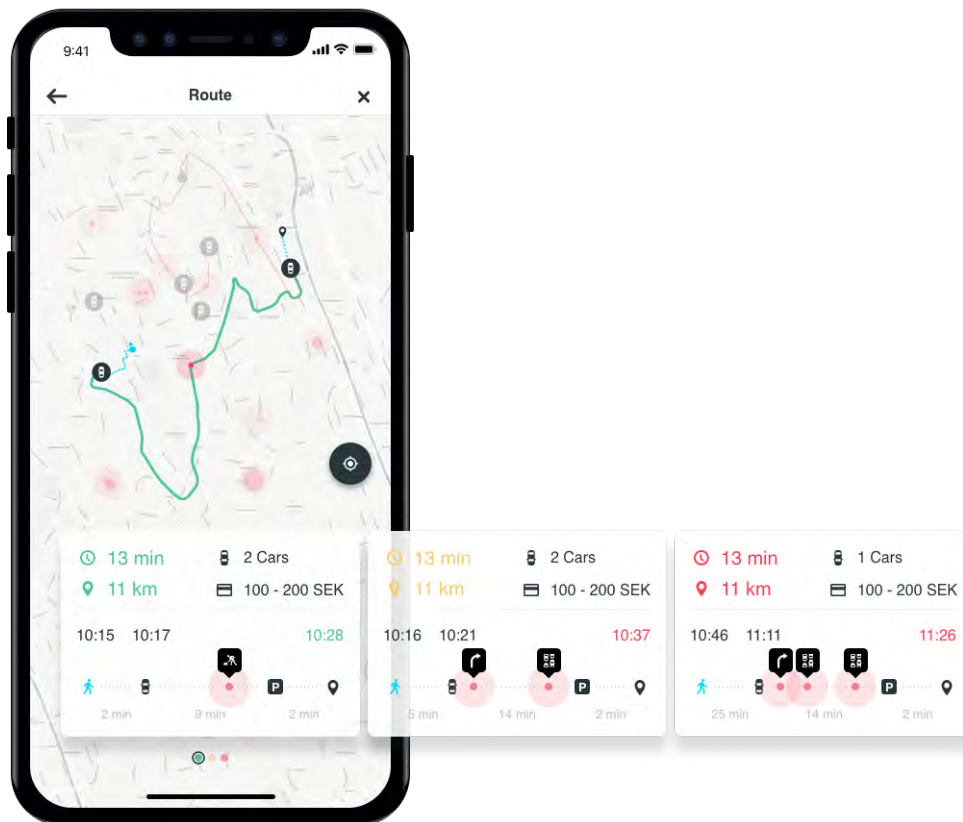


Figure 5.8: Volvo Intuit - Routes

This functionality is not mandatory, because some users are used to drive in the area where they want to drive so they know about the difficult areas. For this scenario, the application still works. The user just books a car and is good to go, as shown in figure: 5.9.

Furthermore, users often getting stressed or angry in traffic because of bad driving habits, poor understanding of other road users, and poor respect of traffic regulations, etc [13]. The **education** part of Volvo intuit helps to educate in good driving behavior. This helps to raise the amount of educated and experienced drivers in traffic. The education system of Volvo Intuit recognizes if a driver is behaving poorly and helps him to reflect on this behavior in order to avoid it in future traffic situations. Poorly behavior can be for example:

List of poorly behavior

- Lane Deviation [9]
- Rapid acceleration [9]
- Being Unaware of Your Surroundings [9]
- Last minute or excessive braking [9]
- Not Using Turn Signals [9]

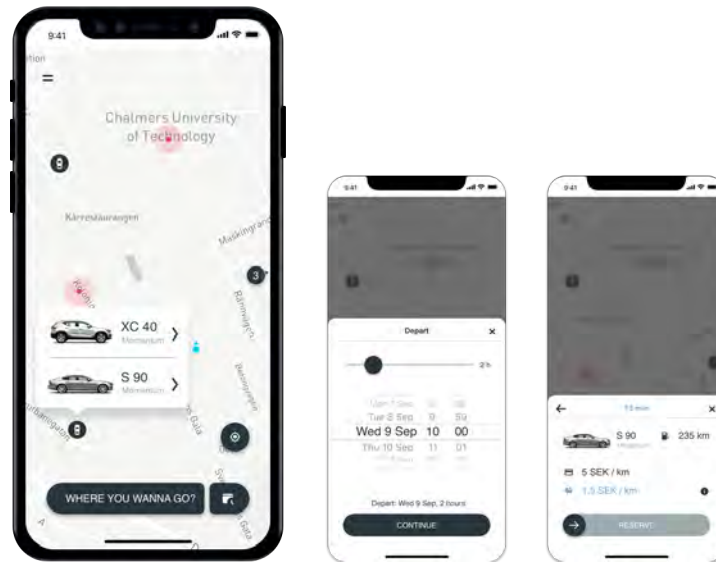


Figure 5.9: Volvo Intuit - Free Ride

- Not Turning Into Your Correct Lane [9]
- Tailgating [9]
- Speeding [9]
- Using a phone while driving [9]
- Dangerous overtaking [9]
- Hogging the right lane [9]
- Running a red traffic lights [9]
- Running a stop sign [9]
- Not understanding roundabouts [9]
- Ignoring Traffic Signs [9]
- Not Checking Blind Spots [9]
- Merging Improperly [63]
- Cutting Other Cars Off [63]
- Not wearing a seat belt [30]
- Eating while driving [30]

The list of poor behavior is generated through insights from literature review (3.10 Literature Review), questionnaire (4.1.2 Questionnaire), and In-Depth Interview (4.3 In-Depth Interview). This list reflects a tiny fraction of what could be poor behavior and requires more studies in order to be fully eligible for the realization of this project. Moreover, this list is not a depiction as a list of poor behaviour by all nations in the globe, because the definition of poor behaviour in traffic varies from culture to culture and country to country, but finds its origins in the regulation of countries by law.

If poor behavior gets recognized by Volvo intuit the driver gets warned with a signal tone and a warning pops up in the infotainment system of the car (3.5.1 Non - Visual User Interaction) as shown in figure: 5.10. Later on the behavior and be seen as a log in the application. The poor behavior gets listed with where it happened with

a description of why it is poor behavior and how to improve. In this way both the user and the renter can profit because good behavior in traffic achieve better results in reducing maintenance and energy costs (3.8.4 Life and vehicle costs with good and bad driver behaviour) for the renter and more safety for the user.

Kopie.jpg



Figure 5.10: Volvo Intuit - Misbehavior Warning

In order to keep the user tight to the system which makes it possible to educate the user over time for good behavior, a **motivation** system got implemented as one of the last features. The motivation system is linked to the maintenance and energy costs because good behavior means less yearly costs for the car and as a conclusion, the car rests longer and can produce more money as a rental car. A part of this money gets funded back to the user as a reward. This means a driver gets a cost reduction of every ride according to his level of good behavior in traffic (shown in figure:5.11).

The rewarding algorithm works like a taximeter as long as the drivers are not doing things like stated in the list of Poorly behavior, the driver is getting a cost reduction for every minute he is driving. This reduction can be higher and lower according to the model of the car which is used and the type of energy which is consumed (electricity or fuel). If the driver misbehaves the cost reduction is temporarily suspended for a few minutes until the misbehavior ends. This rewarding system should motivate and gamify good driving behavior for more driver and traffic safety. Gamification (3.6 Gamification) has proved to be very successful in engaging people and motivating them to change behaviors, develop skills, or solve problems. That's because



Figure 5.11: Rewarding for good behavior in traffic

of the human body releases endorphins during a gamified experience that improves memory and learning abilities.[12] This makes the education of a driver combined with gamification to a perfect combination to improve the driving experience and good driving style.

6

Discussion

This project studies which emotions cause significant harm to the driver and other road users when driving in traffic and how to minimize traffic safety critical errors caused by emotions or a bad driving behavior. Therefore, emotions got investigated (5.3 Safety critical emotions) on safety-critical errors in drivers and traffic safety. Consequently, anger got evidential (3.10.1 Anger, stimulus and behavior) to be the emotion with the highest risk of causing safety-critical errors or bad driving behavior in drivers and traffic safety. In order to minimize traffic safety critical errors caused by anger or bad driving behavior a concept called **Volvo Intuit** (5.8 Volvo Intuit) got created and tested with participants.

6.1 Findings

During the literature review (3.10 Literature Review) several emotions got reviewed (3.1.1 Basic Emotions) and two emotions got detected as emotions which cause significant harm to the driver and other road users when driving in traffic. These emotions were: sadness (3.10.2 Sadness, Stimulus and Behavior) and anger (3.10.1 Anger, stimulus and behavior), especially anger got the special interest of the author by its origin in traffic situations.

From a neuroscience perspective anger is critical while driving because anger is high in arousal (3.1.3 Geneva Emotion Wheel) which lowers the drivers' perception of danger. Arousal is a brain activity which affects cognitive abilities of the drivers to succeed in cognitive tasks like attention, understanding, projection, decision making, and selection of action (e.g 3.10.1 Anger, stimulus and behavior). For this reason, drivers react with behavioral changes while driving angry, as stated in 3.10.1 Anger, stimulus and behavior. Correspondingly, cars need some additional technology in order to deal with emotions in driving and traffic safety.

An expert interview with a psychologist (5.1.2 Psychologist with focus on behavioural therapy), empathized that regulating emotions into a neutral state is a difficult approach. Emotional regulation methods can be useful in regulating emotions, which, on the other hand, are difficult to implement while driving. As a result, attempting to prevent anything that can trigger an emotional reaction could be a strategy for dealing with emotions.

The anger and stress model (5.3.3) is based on the 3.1.5 ABC-Model by Albert Ellis

which helps to define emotional situations. This model helps to build comprehension of why certain situations cause stress and anger in traffic. This is helpful from two perspectives, first, if an AI has learned a certain situation as an emotional scenario (as shown in the figure: 5.6) a scientist or developer can understand the deep learning model produced by the AI. Second, to implement a system which deals with emotions in traffic, researchers and developers need to classify a certain amount of scenarios in order to have a foundation to build on.

While testing the concept Volvo Intuit (5.8 Volvo Intuit) as a proposal of how to minimize traffic safety critical errors caused by emotions or bad driving behavior, it became clear that that dealing with emotions especially while driving in traffic is best practice before and after the emotion. For this reason, emotions should be treated preventive and reactive. The preventive feature called **Prevention**, plans journeys as trouble free as possible and got perceived as a helpful feature because it avoids environmental impact which provokes emotions in traffic. The reactive feature called **Education** is dealing with the influence of traffic participants. This feature is coaching and educating for a good driving style and behavior in traffic because a good driving style and behavior in traffic causes fewer emotions triggered by other driver participants in traffic.

Along with preventive and reactive features a proactive feature called **Evasion** got designed and tested (test results stated in 5.7 Summative Usability Evaluation Results). The proactive feature **Evasion** deals with emotional critical errors while driving. This feature got perceived as problematic in producing an increase in emotional valence (3.1.3 Geneva Emotion Wheel) and resulting in cognitive overload and stress while driving. Additionally, it is difficult to design proactive for emotions, especially for anger because with the best intentions to remain calm, it is very difficult to interact with an emotional especially an angry person.

Furthermore, from the expert interview with a Psychologist 5.1.2 Psychologist with focus on behavioural therapy, and the testing of the feature **Evasion** it became evident that in order to deal with emotions, strategies are needed.

Additionally, reactive features such as education for healthy driving style and behavior have aside effects of rental cars perceiving better treatment and resting longer, fuel-powered cars have less emission depending on sustainable driving behavior, electric vehicle batteries resting longer, and fewer maintenance costs. These side effects have a beneficial effect on the environment and add to the sustainability of automotive cars.

In fact, the next generation car users will be a large percentage of people belonging to Generation Y (defined in 4.2.1 The User). These users will not necessarily own cars and, especially, not those who live in bigger cities where space is rare and public transportation highly available. For this generation car rental and subscriptions services become quite attractive.

In case a good driving style and good driving behavior, rental and subscriptions services have a huge advantage out of a concept as created within Volvo Intuit (4.12 Volvo Intuit, final design) because with planning for trouble-free journeys, cars are less exposed to safety critical areas which reduce the probability of accidents, the education of drivers reduces the probability of accidents caused by bad driving style and bad behavior and rewarding within **Motivation** keeps the user tight to the system which on the other hand has the advantage of further education of the driver for even better behavior and driving style in traffic.

Rewarding and positive reinforcement in driving are aspects of car gamification which gives users satisfaction in driving. Driving becomes a challenge and adds significantly goodwill to good driving style and behavior. Likewise, rewarding produces endorphins in the body of the drivers, which improves memory and learning abilities of good driving behavior with presented reflections of the current ride of what a driver did good and bad and further description of how to improve in driving style.

6.2 Design Process

The design process, within this project, got divided into literature review, user research, qualitative research, defining the problem, ideation, prototyping, evaluation, and iterations.

Literature review, user research, and qualitative research could be seen as the empathizing stage of a design thinking framework that took place at the beginning of the project and gave enough pieces of evidence in order to answer the first research question.

In addition, to answer the second research question, the design process could be continued as a design thinking process by framing the problem space (as indicated in 4.4 The Problem Statement and discovering solutions (as stated in 4.6 Ideation) to the framed problems.

With a broad but superficial knowledge of the distinct topics in the subject, it was feasible to pick the appropriate elements of the subject. The expert interview (4.1.1 Expert Interviews) assisted in the next step to deepen knowledge of the relevant aspects and to formulate this knowledge into insights. The in-depth interview as a follow-up method back proved the insights with the actual user group and guarantees user-centered practice for further development.

To frame the problem methods called point of view (4.4.1 Point of View) and How might we (4.4.2 How might we ...?) got used. Point of view structures discovered problems within the field in a well-structured manner. The advantage of this method is that investigated problems can be simply defined and working on a problem space stays focused on the long run. The designer can always go back and prove if its designed idea solves the problem or not. As a follow-up method, How might we

help to imagine directions of possible solutions, this accelerates the brainstorming process in the ideation stage.

Beyond, within the ideation stage (4.6 Ideation), personas (4.6.1 Personas) and how might we, ideas were created with a focus on the user and the actual problems which got defined. A technique called weighted matrix was used to define the final concept in order to decide on the best appropriate concept. This was essential because only one individual creates the project and collaborative decision-making is not feasible. It is a popular strategy to rate the correct concept according to user-based criteria in order to select the best appropriate solution.

The next step in the ideation stage includes a minimum viable concept (MVC) (4.6.4 Minimum Viable Concept), this is extraordinary but it helps to define the concept and make it feasible with the remaining time in mind. In addition, the MVC made it more simpler to write lo-fi and hi-fi prototyping requirements.

The author worked with formative and summative usability evaluation in the last stage of the project where evaluation and iteration took place. Formative usability evaluation (4.9 Formative Usability Evaluation) has the advantage of being great practice for lo-fi and hi-fi prototypes and participants can be selected in the immediate environment without a pilot study. This makes it possible to test and iterate quickly because the developer does not have to leave his workplace and can perform testing and iteration in a loop. Similarly, summative usability evaluation (4.11 Summative Usability Evaluation) is more complex, providing a pilot study and a rigorous testing schedule for what to test and how. In addition, to match valid outcomes, summative usability evaluation must follow the same rigid framework with each participant.

6.3 Generalizability

In the case of generalizability, this project got conducted with a small sample of people who do not represent a vast majority of the world population. This means the dependability of the findings is not absolute, but it is statistically probable.

For example, Good behavior rules, as stated in 4.12 Volvo Intuit, final design the **List of poorly behavior** is not generalizable for every country or culture. In comparison to India, the bad behavior "Not Using Turn Signals" is in some cases in not possible drivers using the horn in order to attract attention for example to switch lanes. If this is the right way to do it is debatable but some countries and cultures differ in road traffic laws which have to be taken into account when designing a system for good driving behavior and style.

Similarly, the classification of traffic situations by an outside camera (as shown in figure: 5.3), can differ according to used vehicles on routes. For example, a traffic jam can look different in other countries of this world as in western Europe. A traffic

jam can be only made of cars and trucks but in other countries, a traffic jam can consist of cars, bicycles, rickshaws, and even animals.

Along with detection and classification technologies over cameras, facial features of anger is an effect which can be seen as generalizable because as stated in 3.7, anger is an emotion which expresses its state in the same way through all cultures on earth.

6.4 Limitations

Research has a wide range of factors that can influence the research outcome. These factors can be described as limitations of research. Limitations may be weak points in the methodology where the outcome does not ensure generalizability and transferability.[41]

6.4.1 Limitations of Qualitative Research

Qualitative Research regarding interviews with stakeholders and experts can have issues and a possible lack of reliability and dependability. The reason for that could be interviewees providing answers and thus the results of the research could vary depending on various outside influences like the day, time and personal mood. In some respects, the interviewer could be prejudiced before or in the meantime. This prejudice could have affected the way the questions were asked and the answer to them. In qualitative research, concerns about transferability and generalizability arise because the number of interviews and the sampling of interviewees was limited. As a result, the results of the research are not generalizable or transferable.[58]

6.4.2 Limitation of Research

With respect to the research limitations, the formulation of the research goal and objectives were formulated too broad at the beginning, leading to additional research in order to reformulate the goal and adapting to the time frame. Due to the author's experience in writing scientific papers, there was a lack of experience in primary data collection this makes a big change that the nature of data collection method implementation is flawed. With regard to little experience in the literature review, the research may suffer from the lack of previous studies in the research area, which is important to define the scope of work that has been done so far in the research area. Rating the few years of experience in research and producing academic papers of such a large size individually, the scope and depth of discussions in the paper are compromised in many levels compared to the works of experienced scholars.

6.4.3 Language Barrier

Language Barrier could be a problem in qualitative data analysis in interviews and questionnaires. Most of the information gathered was created by people who are not native English speakers. On the other hand, the author is not a native English

speaker either. The translation could have resulted in the loss of information or misinterpretation of content.

6.4.4 Time Limitation

The main issue was the 16-week time factor from mid - January 2019 to the beginning of May 2019. However, because the research objectives were defined in late February, there was little time for the actual research.

6.4.5 Budget limitations

According to the budget, there was a budget limit of 1000 SEK which was only accessible through a satisfying procedure by presenting the purpose to the supervisor and the student counselor who was not manageable due to time constraints.

6.4.6 Limitations of master thesis supervisor support

Master thesis supervisor has partial or limited knowledge in the field of research, which is not a major advantage for research progress. This causes misled research or slow progress in the field of research.

6.4.7 Limitation of Technology

Technology limitation may mean technology that is used for a specific purpose but can only measure a certain accuracy. This can cause errors, but if the technology still delivers better advantages than no technology or other technology, the technology is still of great value.

6.4.7.1 Limitations of measuring facial expressions to detect stress and anger

There are different types of data and media that can be used to measure stress or anger. Measuring facial expressions for emotion from an IR camera is one option, as long as the camera records facial expressions in the correct range of the spectrum. The main limitation of measuring facial expressions is that it is not always available. Low light, facial hair, glasses, head movement, etc. can obscure the recording, and people spend a lot of their time without expressing any clear emotions. The last point is particularly relevant to the driving context, where was found that most time drivers display a neutral expression. This is probably because they are cognitively overloaded by focusing on driving, and in any case, there is no other person in front of them to communicate with their expression. The heart rate is another option. Some IR cameras can provide sufficient information to detect heart rate from patterns of blood flow. And stress can be measured by heart rate.

6.5 Future work

If more time is given, the research will be expanded in the field of sadness, happiness, joy, surprise, and fear. For instance, according to Myounghoon Jeon in "Lessons from Emotional Driving Research"[36] happiness and sadness degenerated driving as much as rage. Accordingly, happiness could be an emotion that could be taken into consideration when continuing Volvo Intuit.

Development can be achieved in driver education. For instance, how to generate quick instructional vectors to make a driver aware of present bad behavior. This could be achieved with iconographic or voice feedback.

Education and motivation showed great potential for further development in the field of gamification. Gamification aspects in driving according to driver and traffic safety seem to be a field of research where new ways of user experience can be developed for the advantage of all traffic respondents.

The rewarding system of the motivation feature within the concept Volvo intuit needs a well calculated financial model, in order to fund users accurately without harming a companies financials.

The emotional heat map as mentioned in 4.12 Volvo Intuit, final design, could not only be an instrument for trouble-free route planning but could also be an instrument for urban planning to discover points of frustration in towns or measure mental feedback on traffic conditions.

Every nation has distinct traffic laws and distinct opinions on what is good driving behavior. Good driving style is more generalizable but behavior within this subject requires more studies which are the fundamental rules that can be tailored to each nation and which rules are individual for every nation.

6.6 Ethical consideration

In terms of Ethical consideration, there are points to consider, such as shared data, rewarding for good behavior, and algorithms which evaluate human behavior.

In the case of shared data, it is to consider to keep collected data from users private. This means any collected data which got shared should not be traceable back to its creator. In return, the user also has to be informed about what data gets shared and consent have to be requested from the user. This makes it possible that data from users can be used in order to secure data privacy of users and at the same time every user can benefit from the shared data which get visualized in an emotional heat-map. Further, if this heat map gets used by third-party companies the profit out of this use should be given back to its creators in the way of making higher

rewarding for every ride. In the case of the last point people even getting more profit out of its created data.

Good behavior, rewarded by an algorithm, sounds like a step in computing free will control. This is ethically and morally critical because who takes control of morality refers to what sanction and acceptability of good and bad behavior in traffic situations? It must be ensured that the rules for these algorithms are created by organizations that are disconnected from the interests of big companies. Otherwise the rewarding and planning (5.8 Volvo Intuit) system can be used form companies as manipulation systems for hidden advertisement and seduction-techniques of the consumer.

7

Conclusion

In conclusion, this project aimed to identify which emotions cause significant harm to the driver and other road users when driving and how to minimize traffic safety critical errors caused by emotional driving or a bad driving style.

In the case of the first research question, which emotions cause significant harm to the driver and other road users when driving? Research showed two emotions which generated evidence of significant harm to the driver and other road users when driving. First, anger and second, sadness.

Sadness showed to be safety critical in behavioral and behavioral changes, such as concentration problems, slowness in disengaging attention, degradation of controlled processing due to self-focus and ruminations, slower steering reaction times, and performance disturbance.

However, sadness whilst driving is not necessarily caused by road or traffic situations. In most cases, sadness is a result of low self-esteem, emotional disorder, or depression. These issues need more research in consideration of driving, which restricts the author to focus on sadness.

Not only for this purpose, the author decided to focus on anger, also because anger facial features are generalizable and look the same through all cultures in the world. This makes it easier for an AI to detect anger.

The problem of the emotion anger and, in particular, angry driving is that anger increases the illusion of control and lowers the drivers' perception of danger. At the same time, anger impairs various cognitive functions, such as attention, understanding, projection, decision making, and selection of action, which are crucial for a safe driving behavior in traffic.

In order to answer the second research question, how to minimize traffic safety critical errors caused by emotional driving or a bad driving style, the author creates a design concept called Volvo Intuit, as a possible answer.

The design concept gave valid insights into how to deal with emotions in vehicles. For example, emotions cannot be treated proactively. This implies reaction if an emotion occurs because, with the best intentions to remain calm, it is very difficult to interact with an emotional especially an angry person. In fact, the interaction

7. Conclusion

with an emotional person can, in worst case scenario increases the emotion in valence or result in cognitive overload and stress.

For this reason, the design concept is dealing with emotions, with preventive and reactive strategies. This includes 3 features, first, to avoid difficult to drive areas to prevent emotions provoked by environmental influence, second, to educate for good driving behavior to prevent from traffic participants influence and, lastly, a motivation feature that rewards the driver for good behavior.

The motivation strategy works with rewarding in order to reduce fund the driver for good behavior. This gamifies the driving experience into a challenge of succeeding in good driving behavior and style. Gamification has proven to be very successful in engaging people and motivating them to change behaviors or developing skills. During a gamified experience, the body produces endorphins which can improve memory and learning abilities. The design concept uses the effect of gamification to make the driver reflect on own driving misbehavior and to challenge the driver for good driving behavior.

The design concept showed some novel interactions with traffic safety critical errors caused by emotional driving or bad driving style but more development and testing must be done in the field of driver education and other traffic emotions such as sadness, happiness, joy, surprise, and fear. The author hopes that the concept or parts of the concept will lead to further development or be used as a catalyst for future work at Volvo Cars.

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A

Appendix

A.1 Personas

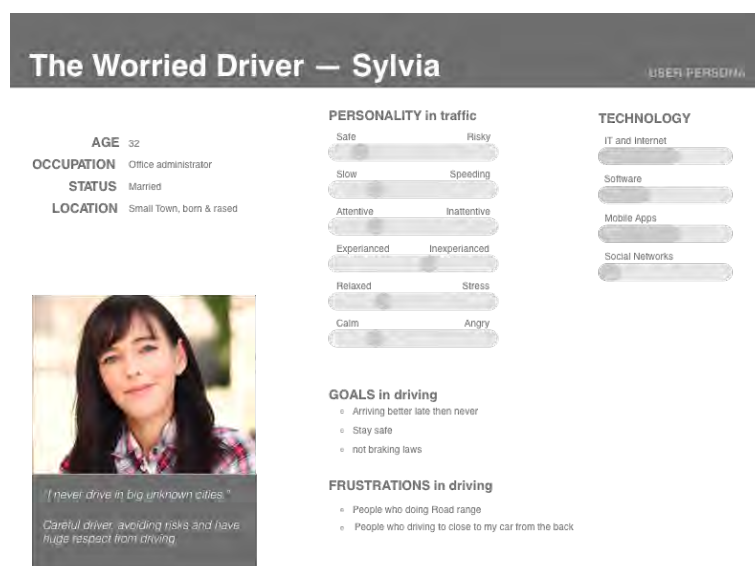


Figure A.1: Persona 01

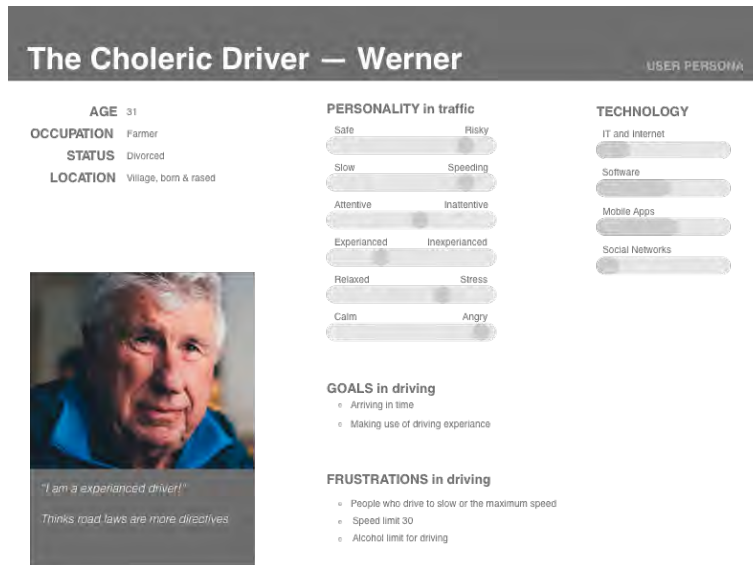


Figure A.2: Persona 02

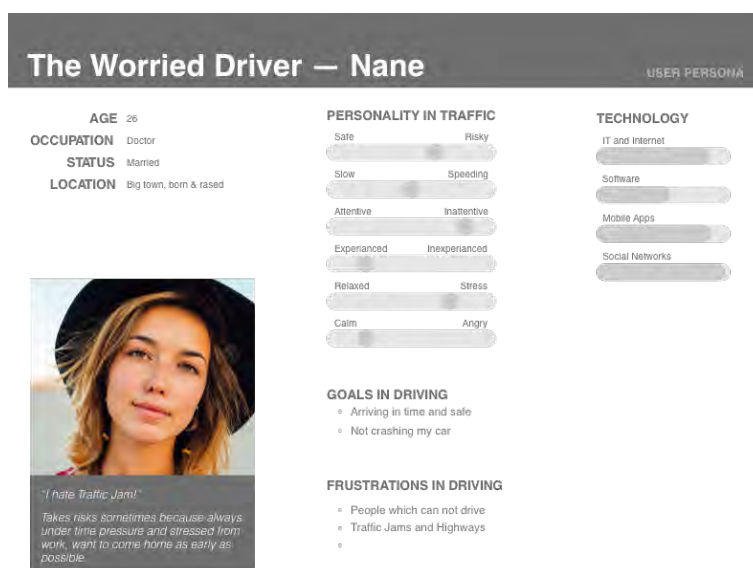


Figure A.3: Persona 03

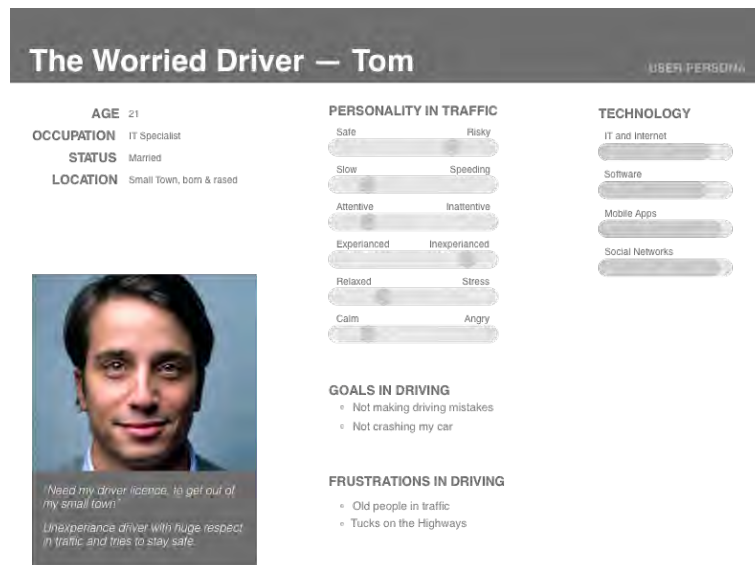


Figure A.4: Persona 04

A.2 In-Depth Interview result

- **Warning Mechanisms**
 - A driver needs support by making decisions (judgement) because anger make humans **less thinking rationally**.
 - A angry driver need to get feedback in a way which is not annoying for him because an angry driver is more likely to reject a recommendation or feedback.
- **Information**
 - A driver needs to know the risks of angry driving because most of the users are assuming that risks of angry driving.
 - A driver need to get information about the risks of emotional driving because the driver knows that it is a risk but has no idea on what he has to take car of.
 - A angry driver need to know why the car took over in a risky / dangerous situation because in order to accept that the driver got disempowered the driver has to know why he could not handle the situation anymore.
 - A driver need always clarity why a system reacts how it reacts because if a driver understand that it just helps him to save its life he has more will to give power away and building up trust.
 - A driver need not to see its biological data life because the average driver is not educated to make sense out of the data.
- **Support**
 - An angry driver need support to focus on driving because anger makes people less focused on driving and more focused on being angry.
 - An angry driver need support in perceiving its environment because anger makes humans less perceiving there environment.

- An angry driver need support by steering and speed because angry non-verbal communication bothers steering and speed regulation.
- An angry driver need active speed limiting because angry driver getting an **illusion of control** and taking more risks.
- A driver need to drive in a flow because stop and go with different speed limits affords more workload and this frustrates the driver first and can result into anger.
- An angry driver need driving flow because there are more likely to change lanes.
- An angry driver need get supported while being angry because anger can make humans egoistic and they do not care for others very much anymore.
- An angry driver need get supported while being angry because angry driver do not act proactive anymore.
- A driver need intelligence that minimizes the user's workload while driving because life is already a lot of workload do not need more.
- A driver need support with minimal interaction because the driver want to interact effectively which means it should react as the driver expect it to react.
- A driver need support while driving because the driver want to minimize driving errors.
- A driver need intelligent systems because they help them to reduce there workload for planing there routs.
- **Deal with Emotion**
 - An angry driver need to communicate its frustration because anger is an emotions which is seeking four justice.
 - An angry driver need a way to use non-verbal communication (hand, foot, body movements, postures, facial expressions) because this helps humans to release anger.
 - An angry driver need a way to use verbal communication (scream , swear words) because this helps humans to release anger.
 - An angry driver need to release or avoid the anger because anger makes cramped muscles and this prevent driver from driving precise.
 - An angry driver need fast progress because anger human less patient.
- **communication**
 - A driver need to another way of communication with other cars because honking in traffic gets easily miss understood and divers feel attacked and getting angry.
 - A driver need to feel justice if someone else is doing traffic violence because traffic violence like Speeding, Running a red light, Not stopping for pedestrians, Not using a seat belt, Drunk driving, Reckless driving makes drivers angry and if a human is angry he seeks for justice.
- **Risks**
 - An angry driver need still to check the speedometer because angry driver are distracted by being angry and not looking on the speedometer any more.

- A driver needs to stay neutral because if traffic, missing a turn, other stupid driver, bad day, relationship issues, or general emotional negative issues bother the driver he tends to get angry while driving.
- A driver need always enough time because less time occur es **stress** and stress supports driver to get angry faster (black powder spark relationship).
- **efficiency**
 - A driver need to come from A to B as fast as possible because the car is just a tool and driving is not the most enjoyable thing for me.
 - A driver needs progress because I hat it to wait.
 - A driver needs efficiency because driving is not a goal in life.
- **cause stress**
 - A driver need to arrive in its planed time because running late makes drivers stressed and stress makes drivers in high workload/concentrations or unexpected negative events easily angry.
 - A driver need a easy and seamless interaction because troubles with in-teractions irritates the driver and can cause anger.
 - A driver need easy to understand because if something is to complex the user feels dump and that makes the user angry
 - A driver need communication to other drivers because the driver bias against specific car brands, in terms of reckless driving drivings style (ex. Audi)
- **data privacy**
 - A driver needs transparency because the driver feels surrendered if data got recorded and the driver has no idea how this impact him.
 - A driver needs transparency because the driver do not want to share its recorded data.
 - A driver needs transparency because I feel not comfortable if government or big companies have access to my data.
 - A driver need transparency when data get recorded because as long the driver knows the date will not be shared or money earned with he trust the system.
 - A driver needs transparency if biological data got recorded because he will not trust the system any more if the data gets shared or used to earn money on it.
 - A driver needs transparency if GPS position data got recorded because he will not trust the system any more if the data gets shared or used to earn money on it.
 - A driver needs transparency if data got traced because the driver feel otherwise to be victim by data abuse.
 - A driver needs to know that only the car has access to its private calendar if he car read the calendar because some driver do not want that other can read what kind of private activities there are doing.
- **User Experiance**
 - A driver needs a good user experience from the very beginning because he pays a lot of money for it.

- A driver needs personalization because that creates less workload while operating the car.
- A driver needs time to get used to intelligent systems because it is difficult to be patronized by a machine which tells you that you are doing something wrong when you should be capable.
- **Trust**
 - A driver needs to trust in the car because the driver has distrust in the electronics which can fail.
 - A driver needs trust towards my car because otherwise it is difficult for the driver to let the car take over in risky and dangerous situations.
 - A driver needs to trust the car because otherwise I fear that the car will assess me wrong and has a wrong view about me.
 - A driver needs something which makes him believe in the judgement of the car because a car is not a moral authority for the driver.
- **Power & in-control**
 - A driver needs to have power to take over because that makes the driver still feel in control.
 - A driver needs to feel in control because the driver does not want to feel surrendered to the car.
 - A driver needs clarification if a car takes over automatically because the driver has to understand why he was not capable to manage the situation, drivers do not like to get patronized by the car.
 - An angry driver needs to give the power to the car because an angry driver has problems to make rational decisions while driving and being angry.
- **Other**
 - An angry driver needs to focus on the road for safety reasons because his attention gets easily drawn away from smartphone, Infotainment system, new gadgets in the car, search how to activate driving assistance, heavy weather situations (like rain, wind, snow), passengers are drawing attention away (talking, arguing, etc.), climate settings, music settings, navigation system, how to connect the smartphone with the car.
- **from the user needs**
 - A driver needs a seamless and trouble-free journey to his destination because without seamless and trouble-free driving stress and anger can occur.
 - A driver needs safe and convenient interactions with the car because troubles with the interaction occurred frustration and stress which can lead into anger.
 - A driver needs an experience that is already good but can get better every day because better is good and personalized can make good things better.

A.3 Weighted Matrix Tables

Table A.1: Weighted Matrix - Visualize Emotion

Criteria	Wgt	Visualize Emotion
Driver Support to minimize driving errors	3.0	3.0
Motivation for good behavior in traffic	3.0	0.0
Avoiding stress	3.0	3.0
Avoiding anger	3.0	3.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	3.0
Seamless and Trouble-free journey	3.0	3.0
Education for better driving	3.0	3.0
Convenient interactions	2.0	0.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	2.0
Driver Support with minimal interaction	2.0	2.0
Reflecting on own driving behavior	1.0	1.0
Not feels like losing control	1.0	1.0
User performs effectively	1.0	1.0
Summmery	35.0	27.0
Rating		Nr.1

Table A.2: Weighted Matrix - AI Route Planer

Criteria	Wgt	AI Route Planer
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	0.0
Avoiding stress	3.0	3.0
Avoiding anger	3.0	3.0
Avoiding Time pressure	3.0	3.0
Avoiding unexpected situations	3.0	3.0
Seamless and Trouble-free journey	3.0	3.0
Education for better driving	3.0	0.0
Convenient interactions	2.0	0.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	2.0
Driver Support with minimal interaction	2.0	2.0
Reflecting on own driving behavior	1.0	0.0
Not feels like losing control	1.0	1.0
User performs effectively	1.0	1.0
Summmery	35.0	23.00
Rating		Nr.2

Table A.3: Weighted Matrix - Proactive ADAS System

Criteria	Wgt	Proactive ADAS System
Driver Support to minimize driving errors	3.0	3.0
Motivation for good behavior in traffic	3.0	0.0
Avoiding stress	3.0	0.0
Avoiding anger	3.0	0.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	3.0
Seamless and Trouble-free journey	3.0	3.0
Education for better driving	3.0	3.0
Convenient interactions	2.0	2.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	2.0
Driver Support with minimal interaction	2.0	2.0
Reflecting on own driving behavior	1.0	1.0
Not feels like losing control	1.0	0.0
User performs effectively	1.0	0.0
Summmery	35.0	21.0
Rating		Nr.3

Table A.4: Weighted Matrix - Emotional Diary

Criteria	Wgt	Emotional Diary
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	0.0
Avoiding stress	3.0	3.0
Avoiding anger	3.0	3.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	3.0
Seamless and Trouble-free journey	3.0	3.0
Education for better driving	3.0	0.0
Convenient interactions	2.0	0.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	2.0
Driver Support with minimal interaction	2.0	2.0
Reflecting on own driving behavior	1.0	0.0
Not feels like losing control	1.0	1.0
User performs effectively	1.0	1.0
Summmery	35.0	20.0
Rating		Nr.4

Table A.5: Weighted Matrix - Emotional Shifter

Criteria	Wgt	Emotional Shifter
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	0.0
Avoiding stress	3.0	3.0
Avoiding anger	3.0	3.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	0.0
Seamless and Trouble-free journey	3.0	0.0
Education for better driving	3.0	3.0
Convenient interactions	2.0	0.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	0.0
Driver Support with minimal interaction	2.0	2.0
Reflecting on own driving behavior	1.0	0.0
Not feels like losing control	1.0	0.0
User performs effectively	1.0	0.0
Summmery	35.0	13.0
Rating		Nr.5

Table A.6: Weighted Matrix - Virtual Assistance

Criteria	Wgt	Virtual Assistance
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	3.0
Avoiding stress	3.0	0.0
Avoiding anger	3.0	0.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	3.0
Seamless and Trouble-free journey	3.0	0.0
Education for better driving	3.0	3.0
Convenient interactions	2.0	2.0
Not making other drivers angry	2.0	0.0
Intelligence to minimize user's cognitive workload	2.0	0.0
Driver Support with minimal interaction	2.0	0.0
Reflecting on own driving behavior	1.0	1.0
Not feels like losing control	1.0	1.0
User performs effectively	1.0	0.0
Summmery	35.0	13.0
Rating		Nr.5

Table A.7: Weighted Matrix - Emotion Mirror

Criteria	Wgt	Emotion Mirror
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	3.0
Avoiding stress	3.0	0.0
Avoiding anger	3.0	3.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	0.0
Seamless and Trouble-free journey	3.0	0.0
Education for better driving	3.0	0.0
Convenient interactions	2.0	2.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	2.0
Driver Support with minimal interaction	2.0	0.0
Reflecting on own driving behavior	1.0	0.0
Not feels like losing control	1.0	0.0
User performs effectively	1.0	0.0
Summmery	35.0	12.0
Rating		Nr.6

Table A.8: Weighted Matrix - Quantify Others

Criteria	Wgt	Quantify Others
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	3.0
Avoiding stress	3.0	0.0
Avoiding anger	3.0	0.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	0.0
Seamless and Trouble-free journey	3.0	0.0
Education for better driving	3.0	3.0
Convenient interactions	2.0	2.0
Not making other drivers angry	2.0	0.0
Intelligence to minimize user's cognitive workload	2.0	0.0
Driver Support with minimal interaction	2.0	0.0
Reflecting on own driving behavior	1.0	1.0
Not feels like losing control	1.0	1.0
User performs effectively	1.0	0.0
Summmery	35.0	10.0
Rating		Nr.7

Table A.9: Weighted Matrix - Emotional Driving Scoring

Criteria	Wgt	Emotional Driving Scoring
Driver Support to minimize driving errors	3.0	0.0
Motivation for good behavior in traffic	3.0	3.0
Avoiding stress	3.0	0.0
Avoiding anger	3.0	0.0
Avoiding Time pressure	3.0	0.0
Avoiding unexpected situations	3.0	0.0
Seamless and Trouble-free journey	3.0	0.0
Education for better driving	3.0	0.0
Convenient interactions	2.0	0.0
Not making other drivers angry	2.0	2.0
Intelligence to minimize user's cognitive workload	2.0	0.0
Driver Support with minimal interaction	2.0	0.0
Reflecting on own driving behavior	1.0	1.0
Not feels like losing control	1.0	0.0
User performs effectively	1.0	0.0
Summery	35.0	6.0
Rating		Nr.8